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The attention demands, based on kinesthetic cues, of stimulus encoding, memory retrieval and response execution.

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THE ATTENTION DEMANDS, BASED ON KINESTHETIC CUES,
OF STIMULUS ENCODING, MEMORY RETRIEVAL, AND RESPONSE EXECUTION

by

Warren Dale Walsh

A Thesis
submitted to the Faculty of Graduate Studies
through the Faculty of
Human Kinetics in Partial Fulfillment
of the requirements for the Degree
of Master of Human Kinetics at
The University of Windsor

03-100

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ABSTRACT

THE ATTENTION DEMANDS, BASED ON KINESTHETIC CUES, OF STIMULUS ENCODING, MEMORY RETRIEVAL, AND RESPONSE EXECUTION

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The present study was primarily designed to determine the attention demands required by the retrieval of kinesthetic sensory information from memory. Traditionally three principal stages in processing information which have been delineated are encoding, retrieval of information from memory, and response execution. As it was necessary to isolate the memory retrieval process, it was also possible to assess the attention demands of stimulus encoding and response execution.

A total of thirty male and female students from Introductory Psychology participated in two one-hour sessions. The apparatus consisted of two pantographs which were in a one-to-one correspondence with two handles manipulated by two experimenters. On the first day, subjects learned three movement lengths--4, 9, and 13 centimeters--which were presented to the left hand without visual and auditory cues. The movement of the left pantograph was guided, with all movements being straight away from the subject. When the subject could reproduce the distances five consecutive times within a 10% deviation from the criterion

distance, it was considered that the lengths had been encoded into memory. Retention of the lengths was measured after five minutes and again after 24 hours. After relearning of the movement lengths on the second day if needed, the experimental phase was administered. Two forms of retrieval--cued and non-cued--were included. In cued retrieval the lengths to be reproduced were known before the recall performance commenced. In non-cued retrieval the lengths were not known until after the commencement of the actual retrieval performance. Subjects were required to retrieve the lengths by pushing the left pantograph forward. During encoding, subjects compared two of the learned movement lengths and were required to determine whether the two presented lengths were the 'same' or 'different'. In response execution, the subject performed a 21-centimeter movement by pushing the left pantograph forward until the movement was stopped. The attention demands of each of the processing stages were inferred from a subsidiary task of shadowing with the right foot a kinesthetic sensory input presented to the right hand. The technique of motor shadowing appeared to be a sensitive measure of the attention demands of memory processes requiring continuous information processing throughout the presentation of the kinesthetic sensory input.

There was no difference between the sexes with respect to the processing of kinesthetic sensory information, but contrary to postulates of many researchers, each of the

memory processes demanded attention and, hence, required access to central processing capacity. The greatest attention demand was during the condition necessitating retrieval of movement information not known prior to the actual retrieval performance. As all processing stages demand attention, it appears the question of where selection occurs may be inappropriate and more effort should be directed towards quantifying the relative demands of each stage depending on the nature of the activity.

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CHAPTER I

INTRODUCTION

Throughout the past twenty-five years there have been numerous efforts to determine how man processes the information which is continually presented to him from the environment. The verbal studies of Cherry (1953a, 1953b), Broadbent (1958), and Moray (1967) demonstrated that, although man can selectively attend to one message when another message is presented simultaneously, there are certain aspects of the unattended message which may be detected. However, when a number of sensory inputs are presented simultaneously, at some point between the reception of the stimuli and the execution of a response there appears to be a bottleneck in the amount of information processed. The phenomena of selection and allocation to particular incoming stimuli in information processing is referred to as selective attention. Although the two extremes of 'Early Selection' (Broadbent, 1958, 1971; Moray, 1959, and Treisman, 1960, 1964a, 1964b, 1964c) during perceptual analysis of stimuli, and 'Late Selection' (Deutsch and Deutsch, 1963; Norman, 1968, 1969a) during response execution have been investigated extensively, the dilemma of where selection occurs remains unresolved.

One explanation for man's processing limitation was proposed by Peterson (1969) and later supported by Posner and Boies (1971) and Keele (1972, 1973). It was suggested

that while some stages in information processing, from the reception of the stimuli to the final output, may require attention, others do not. Processing of information from more than one task may proceed in parallel provided two attention demanding stages within each task do not overlap, necessitating simultaneous access to the central processing capacity.

Moray (1967) and Kahneman (1973) considered there was a more general functional limited capacity processor in which attention may be allocated depending on the demands of the task. Hence, any performance decrement when performing two tasks simultaneously could be attributed to the limited processing capacity of the performer and the attention requirements of the tasks.

The two above explanations for the limitation in processing are not mutually exclusive, each accounting for the limitation of performing two tasks simultaneously. Should it be true that certain processing stages do not require attention, as purported by Peterson (1969), Posner and Boies (1971) and Keele (1972, 1973), then the stages would accordingly not require access to the central processing capacity and this would therefore permit parallel processing. Furthermore, two tasks could be carried out simultaneously provided the processing stages requiring attention did not exceed the total

capacity available..

While a person is processing the information from the environmental display, he is concurrently receiving another flow of information from memory, which bears directly on his success and is no less important than the display information. This process is referred to as memory retrieval and, like any of the stages in information processing, it is conceivable that a bottleneck in processing may exist here.

As James (1890) noted:

We make search in our memory for a forgotten idea, just as we rummage our house for a lost object. In both cases we visit what seems to us the probable neighbourhood of that which we miss. We turn over the things under which, or within which, or alongside of which, it may possibly be, and if it lies near them it soon comes to view (p. 654).

There has been little consideration given to the possibility of a bottleneck existing between memory contact and the retrieval of all the appropriate information for the desired response. This has largely been due to the problems isolating the various stages of, encoding, memory contact, retrieval, and response execution, as well as a strong belief that memory retrieval does not require attention (Keele, 1970, 1972, 1973).

Extending the view of Posner and Boies (1971), Keele (1972) proposed a theory to explain the fact that in some situations parallel processing may occur. Within this theory the question of a possible bottleneck in retrieval

from memory was considered. Keele suggested that there were two distinct stages in information processing. The first stage involved the reception of information from sensory events and the retrieval of information stored in memory concerning the sensory events. The next stage involved any mental operations which occurred subsequent to the retrieval of information from memory. Keele suggested that of the two processing stages, memory retrieval did not appear to require attention, and hence could be discounted as the locus of a bottleneck in information processing. The rationale for this view was based upon the studies of memory contact of more than one source of information simultaneously (Karlin and Kestenbaum, 1968; Morton, 1969; Hawkins, 1969; Biedeman and Checkosky, 1970; Garner and Felfoldy, 1970; Keele, 1970, 1972). To say that subsequent memory retrieval does not require attention meant that if more than one source of sensory information impinges on a person at a time, all the sources activate information stored in memory without interfering with each other. Although it was justifiable from this research to conclude that more than one stimulus may contact memory simultaneously, this cannot be used as tangible evidence to support the notion that the retrieval of all information for the appropriate response does not require attention. From the studies in the verbal domain, examining the retrieval of words from memory under

different conditions (Cohen, 1966; Anderson and Bower, 1972, 1974; Tulving and Thompson, 1973; Posner, 1973; Wicklegren and Corbett, 1977), it has been concluded the retrieval of information from the memory store involves the specific operations of search and recovery.

Posner (1973), while recognizing that memory retrieval may not require attention, talked of retrieval in terms of effortful and effortless operations. When a new input presented to a subject was not identical with information stored in memory, then the retrieval process may be effortful. By inference, it was suggested that the memory retrieval process may require attention, and even in effortless retrieval the person's attention is directed to parts of memory in which it is likely more information about the particular stimuli is stored.

Keele (1973), perhaps the leading exponent of the view that retrieval from memory does not require attention, seems to have contradicted himself when he suggested that it was highly speculative to suppose that, with little practice, memory retrieval and response initiation both require attention. In fact, Keele continually makes reference to instances in which retrieval may require attention rather than allocation of attention being determined by the requirements of the specific processing stages. As Keele states:

A persons' efficiency in interacting with his

environment is limited by the amount of time and attention to retrieve information . . . not only physical skills but the process of thinking in general depends on retrieving and assembling information from memory (p. 75).

Keele, however, considered any retrieval processes which are complicated may be viewed as several substages of retrieval and mental operations. The mental operations of comparing, evaluating and re-directing of the retrieval process may be attention demanding, while the actual retrieval per se is not. Such a view leaves one rather bewildered as to what Keele really considers retrieval in terms of its attention demands. It would not seem conceivable that the flow of information from memory concurrent with the reception of stimuli would be an automatic process.

Summary

In the investigations of selective attention there have been many attempts to determine when the limitation of the human information processing of simultaneous inputs occurs--early at the reception of the stimuli stage or at the later stage of response initiation. While the two extremes have been investigated extensively, at present, the knowledge of the contribution of memory retrieval to the bottleneck in processing of information remains obscure.

Although from verbal research memory retrieval

appears to involve distinct operations, there has been limited research directed at this aspect in the processing of kinesthetic sensory information and involving motor responses. This has largely been due to the problem of isolating the processes of encoding, memory contact and retrieval, as well as a strong belief that memory retrieval does not require attention. However, the latter view is based on limited research and, therefore, a study examining the question of memory retrieval, employing the kinesthetic sensory system, cannot but add to the existing scarcity of scientific knowledge available on the memory retrieval process.

Definition of Terms

1. Cued Retrieval: the information necessary for the appropriate response is available having been indicated by a cue prior to the event.
2. Direction: the line or course extending away from, or to, a given point through space.
3. Distance: the length of, or extent of, a movement.
4. Divided Attention: the requirement of performing two tasks at the same time where one task is only permitted as much central processing capacity as the other task permits.
5. Encoding: the transformation of physical energy into a representation which may be stored in memory.

6. Kinesthesia: sensory modality concerned with the conscious perception of movement and orientation of parts of the body with respect to each other and the body as a whole.
7. Learning: relatively permanent change in behaviour due to reinforced practice.
8. Long Term Memory: relatively permanent storage of information as a result of rehearsal.
9. Memory: the learned capability for responding to something.
10. Memory Contact: the process whereby the encoded representation of a stimulus is matched with a newly presented stimulus.
11. Memory Retrieval: the recovery from memory of all information for the desired response.
12. Memory Store: the system within the human mechanism where the encoded representation of a sensory stimuli is retained.
13. Memory Trace: the representation of a sensory stimuli in the memory store.
14. Motor Shadowing: reproducing simultaneously movement presented through the kinesthetic sense modality using the motor system adhering to all characteristics of the movement.
15. Non-cued Retrieval: the information necessary for the appropriate response is unpredictable being

indicated by a cue at the time of the event.

16. Recall: the process of being able to bring from memory the match of all items presented in the sensory stimuli.
17. Recognition: the process of being able to distinguish from a group of items whether an item is one which was presented as a sensory stimuli.
18. Response Initiation: the execution of a motor program which is deemed pertinent by the particular stimulus presented.
19. Retention: the preservation of items in memory.
20. Selective Attention: the process by which a person attends to certain sensory inputs while ignoring others.
21. Sensory Information: information which is derived by man from the various sense receptors of the body.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Verbal studies have adequately shown that man is limited in his information processing capacity and therefore there are selection processes operating on incoming stimuli whereby the relevant stimuli are separated from all the stimuli presented in the stimulus events. The question of the processes involved in memory retrieval have been studied in the verbal domain (Sternberg, 1969; Anderson and Bower, 1972, 1974; Keele, 1972, and Reed, 1976). However, there has been limited research reported investigating memory retrieval employing the kinesthetic system and requiring processing of kinesthetic inputs necessitating motor responses.

The present chapter is devoted to studies pertaining to the question of limitations in information processing, in particular, the possibility of a bottleneck during the retrieval of information from memory. The first section includes studies of simultaneous memory contact which have led to the conclusion that memory retrieval does not require attention. The second section includes studies of memory contact in a serial manner thus refuting the idea of retrieval not requiring

attention. Other studies directly examining memory retrieval are also incorporated in this section. The third section contains studies which have employed the dual task interference paradigm. The final section is an explanation of the nature of information processing.

Simultaneous Memory Contact

There has emerged in recent years, a strong belief that the retrieval of information from memory is a non-attentive process, with sources of information being able to contact their representations in memory simultaneously.

Karlin and Kestenbaum (1968) measured reaction times to a visual stimulus followed, after a predetermined time delay, by an auditory stimulus with the response requiring the subjects to depress a key with the left hand for the visual display while the right hand was used to respond to the auditory tone. The interstimulus intervals were varied between stimulus onsets from .90 to 1.15 sec. For the visual display there was a choice of five alternative responses, one for each finger, while for the auditory tone there were two buttons actuated by the index and middle fingers in response to high and low tones respectively. The delay of a second response was found to depend on the time since the first response and not on memory retrieval time to the second signal, which confirmed the previous findings of Welford (1952), Craig (1964), and

Bertelson (1966).

Morton (1969) required subjects to sort cards into piles. With two redundant sources of information requiring a single response, there was faster sorting than cases in which there was a single stimulus cue. From the data it was inferred that the two sources of information simultaneously contacted memory and hence there was no interference. Morton considered since in addition the two sources of stimulus information indicated the same response, response facilitation might be expected.

Hawkins (1969), in a series of three experiments using cards varying on three dimensions (form, colour and size) required subjects to indicate as fast as possible whether the stimuli were physically identical or different when pairs were presented varying along one or more dimensions. The results indicated that when multi-dimensional stimulus information is relevant, the stimulus dimensions are compared in parallel; and comparisons terminated upon the detection of information sufficient for a correct response.

From two experiments designed to investigate the effects of information load (number of alternatives) and stimulus--response code in each of two simultaneously performed reaction time tasks, Schvaneveldt (1969) concluded that there was an overlap in the processing of stimuli which contradicted the single-channel hypothesis

(Welford, 1952; Broadbent, 1958) which would predict that stimuli must be processed in a serial manner. The subjects were required to respond both verbally and manually on each trial for the two tasks, with verbal and manual responses done simultaneously. The stimuli consisted of numerals 1-8 which were visually presented to the subject on a panel and the manual response was made on two response buttons in front of the panel using the index finger of each hand. The verbal response activated a noise-operated relay to enable reaction time to be measured to the nearest milli-second. Although parallel processing must have occurred to permit reaction times to be unaffected by the condition requiring the two tasks to be performed simultaneously (compared to reaction times when the tasks were performed alone) the study was unable to determine at what stage parallel processing occurred. Schvaneveldt, like Hawkins (1969), suggested that the significance was not in fact that two tasks could overlap in processing, but rather to determine what aspects in information processing in two tasks can be performed together and to develop an information processing model to deal with situations that produce overlap.

Biederman and Checkosky (1970) varied stimuli on two dimensions (size and brightness) either of which was able to facilitate the correct response. The stimuli were gray circles mounted on white paper centered on glass

slides. Nine stimuli were presented from all combinations of three shades of gray (6, 9 and 15 ft. l) and three circle sizes (diameters, 10, 13, and 16 mm). The subject's index fingers rested on plastic keys, which activated microswitches. A display card showing the stimulus and their assignments to fingers was placed by the response panel and remained there throughout the experiment. Two stimuli were assigned to two responses. In the size condition, the two stimuli differed only in size, and brightness was held constant. In the brightness condition, the two stimuli differed only in brightness and the circles were of the same size. In a redundant task condition, the stimuli differed on both dimensions. The presence of the redundant, relevant stimulus dimension resulted in a shortening of reaction times compared to a condition where such a dimension was not present.

Garner and Felfoldy (1970), from a series of seven experiments, also found a lack of interference when multiple sources were redundant when subjects were required to sort decks of stimulus cards. Thirty-two white stimulus cards were divided into two piles corresponding to the two levels of a dimension. The task was to sort as fast as possible without making any errors. The cards were to be sorted into piles of: 16 each of two different stimuli; 16 each although the two different stimuli were formed

by using two dimensions in a correlated fashion; eight cards each of four different stimuli which were formed from the orthogonal combinations of the two dichotomous dimensions. With this third deck, subjects were also required to sort separately by each dimension. It was concluded by both Biederman and Checkosky (1970) and Garner and Felfoldy (1970) that lack of interference when the multiple sources of information were redundant was compatible with a model allowing different dimensions to be processed in parallel with a single response initiated as soon as there was sufficient information for a correct choice.

In a series of experiments (Keele, 1970, 1972; Keele and Boies, 1973) the types of decisions required for the successful completion of a task were varied by altering the input and output modes in order to determine the conditions in which multiple sources of input would interfere with each other. It was suggested that the stimulus and responses were composed of attributes which included both the number of dimensions (colour, hue) within the stimulus or response component, and the number of components that were represented in the display. Consequently, stimuli varying along two or more dimensions required that two or more channels and sources of inputs be processed assuming that none of these dimensions were irrelevant. The response could either be unitary or a

combination of responses which would also have an effect on the time to elicit the criterion task.

In the experiment by Keele (1970), two tasks were set up; an information conservation task in which each signal required a unique response; and an information condensation task which demanded that only one response be initiated. However, more than one stimuli could elicit the same response. Analysis of the mean reaction times led Keele to conclude that condensation had different effects on reaction times depending on the number of stimulus attributes in the stimulus. The reaction times for conservation tasks were significantly greater indicating that the decision of which response to make was a memory retrieval problem since, when the stimulus was introduced, the response key assigned to that stimulus had to be retrieved from memory. The data supported the contention that when two or more stimulus attributes had to be processed, but only one response elicited, the reaction times were no longer than when only one stimulus attribute was presented. Keele concluded that memory retrieval occurred in parallel but that subsequent mental operations were attention demanding. Interference in processing multiple signals was primarily due to the limitation of the capacity system to indicate independent responses simultaneously. The results obtained by Keele could also be explained in terms of the Theory of Response Conflict

(Reynolds, 1964). Reynolds suggested that there were two kinds of conflict; the conflict as to what response to make to a particular stimulus, and the conflict between making two different responses to different stimuli. It was evident that reaction times increased when two or more responses were required of the stimulus event presented. When one response tendency was selected, all the other responses were temporarily inhibited. Two or more stimulus attributes which required only one response did not increase the processing time within the central processing capacity system. Keele proposed that if it could be shown that irrelevant information must have contacted memory even though it did not interfere with processing the relevant information, then processing limitations were subsequent to memory retrieval. One indication that irrelevant information contacts memory was the Stroop Effect (Jenson and Rohwer, 1966). The reaction time to name a colour increased when the colour printed out an irrelevant colour word (e.g., the word GREEN is presented in red ink, the correct response is red). One interpretation of the Stroop Effect is that it is not during the memory retrieval stage that interference occurs, but as a result of simultaneous memory retrievals--the two sources of information, colour and form, lead to conflicting responses. However, to ensure that it was not the retrieval stage per se that results

in the Stroop Effect it was necessary to demonstrate that non-colour words caused no interference. Keele (1972) presented simultaneously two sources of information form and colour, only the latter being relevant to a key tapping response. When the irrelevant form spelled a word, such as GLASS, no interference with processing the relevant colour was found. Yet it was concluded that the irrelevant information had contacted memory because the word meaning was changed, such as to GREEN, the time to respond to the colour of ink increased. A discrimination of meaning depends on information stored in memory. It was concluded that memory retrieval is a non-attentive process, with response conflict occurring when the words were different colour names from the ink colour. Irrelevant information did not delay the processing of relevant information although when the irrelevant information led to a conflicting response, there was interference present as indicated.

The above mentioned studies would indicate that parallel processing may occur up until memory contact. However, just because stimuli may elicit the appropriate memory representation almost spontaneously, it is unlikely that this representation contains all the appropriate information for the desired response.

Serial Memory Contact

While the preceding section provides credence for the

notion that memory contact may not require attention, studies of memory contact in a serial manner would indicate early perceptual selection between inputs. Some of these studies are reported in the present section together with the work of Norman (1968) who made the point which is paramount in the present thesis. Although, memory contact may occur simultaneously, this does not necessarily mean all information necessary for the response is provided from the stimulus itself, other stored information having to be retrieved.

Using different patterns of 10 lights as stimuli Siebel (1963) required subjects to respond by depressing corresponding patterns of simultaneous keys in a ten-key keyboard, one key assigned to each finger. After more than 75,000 discrimination reaction times for each of three subjects, average reaction times during 1,023 alternative conditions were more than 25 msec. less than reaction times under a thirty-one alternative conditions.

In an experiment by Broadbent (1967) involving serial keytapping, it was evident that when two reactions are compatible there may be considerable parallel processing. However, when the reactions are incompatible there was no evidence of any sharing of capacity during the initial 250 msec. In addition, the processing of the second signal was relatively ineffective even after the first response was completed. The shortest inter-response

interval in this condition was substantially longer than the control value of the second reaction time indicating a prolonged disruption of the secondary action by the occurrence of the first. If the processes that precede response execution require no attention and occur in parallel, there is no special reason for a variation of stimulus-response compatibility to affect the inter-response interval function. The locus of the difficulty in an incompatible situation is in the stages of retrieval and selection of the appropriate response according to this experiment, rather than being a non-attentive process (Keele, 1973).

Keele (1967) varied the reaction time of button tapping in response to lights, changing the compatibility of the S - R relationship. In a second task, the subjects counted backwards by ones, threes or sevens from a three digit number presented at the beginning of a trial. When the two tasks were performed together, tasks with long reaction times interfered considerably more than did tasks with short reaction times. While Keele's (1967) results, which were in direct contrast to Karlin and Kestenbaum (1968) and Schvaneveldt (1969), were attributed to lack of practice, this reason cannot possibly be given to account for the overcoming of the inability to initiate independent responses without interference as displayed by Seibel's (1963) subjects following extensive

practice.

A refutation of the notion that retrieval does not require attention was isolation of the effortless retrieval phase by Hart (1967) in two experiments to evaluate whether people could accurately monitor the contents of their memories when they were unable to retrieve those memories. When required to recall previously learned paired associates constructed from combining stimulus words with response trigrams, the subjects were asked to predict which unrecalled response items they would be able to recognize. Stimulus words were varied in their association value, with two groups of words being chosen. One group consisted of words which occurred over one hundred times per million and the other group containing those which occurred once or less per million. The response words were taken from a list of three place consonant syllables. Sixteen trigrams were chosen from each of three levels of association value; 10% or less, 50% and 90% or more. The trigrams were randomly paired with the stimulus words to form the paired associate learning list. The randomization assignment of words to trigrams was restricted so that equal numbers of the two association groups were present at each of the three trigram association levels. As a part of the recall requirement, for associations which were not recalled, subjects were asked whether they would be able to recognize the

learned association. This was followed by a multiple choice recognition test. In the second experiment, rather than make judgements on whether they would be able to recognize the words dichotomously yes or no, subjects made 'feeling of knowing' ratings. The results indicated that the subjects were able to make relatively accurate predictions about recognition failures and successes, suggesting what Hart considered a memory monitoring process.

Norman (1968) suggested that various sources of sensory information may contact memory simultaneously. "The sensory information can activate its image in storage without any intervening cognitive processes" (p. 526). This automatic matching does not imply immediate knowledge of everything related to the stimulus. However, the point is made that subsequent to this contact an attention mechanism is necessary to select from the associations of stored representation and sensory information that appropriate material to be retrieved to achieve a satisfactory output. It was proposed that this selection or retrieval occurs through repeated queries of the storage system until the satisfactory output is achieved.

After contact with memory has occurred then the attention mechanism might select for the processing of those sensory inputs that seem most important and relevant by

considering stored attributes of each input as well as physical attributes. The outputs of the storage system which have the highest levels of activation (Morton, 1969) are then selected for further processing. Norman (1968) suggested that a possible solution to the search process is to let each output of a retrieval be the guide in the next attempt. The strength of the output can be used directly by the decision process. The observed strength of the output can be compared with a decision criterion (recognition) or by choosing the item corresponding to the greatest strength observed (recall).

Use of Dual Task Interference

The principle behind the use of primary and secondary task technique in examining the information processing capacity of man is that the joint capacity demand of concurrently carrying out the two tasks should exceed the total capacity available (Poulton, 1965). While total capacity demands does not exceed the total capacity available, performance as a whole and of particular processing stages should continue unimpaired. Only when the total capacity demand (joint capacity demand of primary and secondary tasks) exceeds total capacity available will interference with performance occur. The degradation in performance of being required to perform two tasks (often known as the 'divided attention

effect') is one of the principal sources of evidence in support of the thesis that man is limited in the amount of information that he can process per unit time (Broadbent, 1958; Norman, 1968; Treisman, 1969, and Posner, 1973). As Johnson et al. (1970) noted, "the 'divided attention effect' has been used as a methodological vehicle for research in memory" (p. 164). In an experiment to determine the validity of this method using a tracking task and verbal task examining word recall, Johnson et al. found that tracking error was a direct function of the difficulty of the verbal task, and this result seems to validate the use of divided attention as a means of monitoring information processing during the encoding retention and recall of words. In the study the subsidiary task was tracking which required continuous information processing while subjects were required to recall previous learned words. The order of recall determining the experimental conditions were: unordered, ordered, forwards, backwards and alphabetical order. It was assumed that each recall condition was indicative of increasingly difficult forms of retrievability. Therefore, they would likely provide an increasingly greater demand on the response selection process to be verified by the degradation in performance of the tracking task. A control condition in which subjects were required merely to count from twenty-two to twenty-six while tracking

would require little response selection and, therefore, provide a measure of performance of response execution only and tracking simultaneously. Each trial lasted twenty-one seconds with recall commencing after five seconds and being completed within ten seconds. It was concluded that tracking error was a direct function of the difficulty of the verbal tasks indicating that the difficulty of the process of response selection or retrieval was dependent on the demands on the information capacity mechanism.

Trumbo and Noble (1970) employed the dual task interference technique to study serial verbal learning with the information processing defined in terms of four stages. It was concluded the stage of response selection was an important limitation on dual task performance. On the basis of previous studies involving pursuit tracking as a primary task in a dual task situation (Noble, Trumbo, and Fowler, 1967; Trumbo, Noble, and Swink, 1967) it was predicted the performance in serial verbal learning would be interfered with when a second overlapping task required response selection decisions. It had been shown through isolation of encoding, response selection and response execution processes that the capacity to perform a primary task without interference from a second overlapping task appeared to

be limited by the subject's capacity for response selection decision. Therefore, through selection of two tasks rather different from those previously used, Trumbo and Noble (1970) considered that the possibility of generality would be substantially increased. Sixty male subjects were assigned randomly to ten task conditions. The primary task required the serial anticipation learning of consonant, vowel and consonant lists, presented at a three-second rate. An array of five red jeweled lights mounted on a vertical panel formed an arc at a viewing distance of 20 inches. Five micro-switches were mounted to accommodate the five fingers of the left hand, the left forearm placed on a rest. In one of the five secondary task conditions, there was an anticipatory response task with the subject required to predict each light by pressing the spatially corresponding button. A free response, information creating task required subjects to generate a random sequence of responses with the middle light only coming on to cue each successive response. The shadowing (response execution) task required subjects to press the spatially corresponding button after the occurrence of each light. The no overt-response task required subjects to "attend to and learn" as much as possible about the sequence of lights, but without overt responding to the secondary task. The control condition had no secondary task with subjects merely

attending to pursuit tracking. There were twenty-five dual-task training trials preceded by three familiarization trials: one requiring shadowing consonants, vowels and consonants, the second shadowing lights and the third shadowing of both sets of signals.

Performance on the serial learning task was affected by secondary task requirements. Tasks requiring the selection of anticipatory responses or responses in random sequences resulted in decrements in primary task performance while tasks requiring response execution or signal processing without overt responding produced no interference. Hence, the response selection stage was seen as an important limitation on dual-task performance and could realistically be a locus for a bottleneck in any model depicting information processing.

Posner and Boies (1971) and Allport et al. (1972), while not examining retrieval, claimed the encoding stage of information processing was a stage not requiring capacity and therefore may proceed without interfering with other operations. Posner and Boies (1971) performed an experiment presenting two successive letters to subjects requiring the subjects to respond "same" if the letters were physically identical. A further experiment was conducted using mixed uppercase and lowercase letters requiring a response "same" if both vowels or both consonants were physically identical. The improvement in reaction times

for preparation (determined by varying warning signals) and encoding together was almost exactly the same as that obtained separately for the preparation and encoding functions.

In the consonant vowel consonant experiment, there appeared to be a more substantial departure from additivity although these were not statistically significant due to high variability among subjects in this condition. From the additivity of improvement due to preparation and encoding, it was suggested that the two processes can proceed in parallel without interference, even with only a 150 msec. interstimulus interval when the functions were changing rapidly. Thus, the contact between an external stimulus and its representation in memory did not appear to require processing capacity. However, Posner and Boies (1971) established limited capacity results when mental operations such as response selection or rehearsal were to be performed on the encoded information. After memory contact it was necessary to retrieve information necessary for the correct response. This retrieval is commonly considered synonymous with what Posner and Boies labelled response selection. It was suggested that "attention in the sense of central processing capacity is related to mental operations of which we are conscious, such as rehearsing or choosing a response (retrieval), but is not related to the contact between the input and long-term memory" (p. 407). This view would tend to infer that while information

processing may occur in parallel up until memory contact. Thereafter the limitation or bottleneck in processing of simultaneously presented stimuli may occur in retrieval or selection of the appropriate response or its execution.

Comstock (1973) was critical of Posner and Boies (1971) claiming that the length of exposure duration of the first letter of two successive letters which often remained present throughout the msec. interstimulus interval may permit switching of attention from the primary task of encoding letters to deal with the secondary auditory probe. Furthermore, it may have been that encoding the first letter and reacting to the probe did not exceed the total available central processing capacity (Moray, 1967; Kahneman, 1973). An experiment was conducted to control for both these aspects which may have been present in the studies reported by Posner and Boies (1971). Two levels of probe task difficulty were employed called Type A and Type C reactions (Donders 1969). Posner and Boies used Type A reactions as the probe task in their studies and Type C were used to increase the load on central processing at the time of encoding the first letter. Also, on some trials, the first letter was only displayed for 15 msec. and was subject to visual masking using a pattern and random dots. Type C reaction required the subject to press a key to noises coming in the right ear although

noise bursts could occur in either the right or left ear. In the Type A reactions, all noise bursts were presented to the right ear and required a simple button press to each burst. While there was no significant difference due to the type of reaction task, when the first letter was followed by visual masking of random dots reaction time to probes was significantly increased. This suggests that subjects were forced to commence encoding the first letter as soon as it came on. Hence, the "no mask" conditions and the conditions employed by Posner and Boies may have allowed time for subjects to switch attention to begin processing on the probe task and still return to the primary task in time to encode the first letter before it disappeared from the screen or from short-term visual store. The increase in reaction time would not be expected if encoding required no capacity, because in that case processing a probe would not be detracting from processing of the letter and vice versa.

Motivated by the conflicting results of Posner and Boies (1971) and Comstock (1973), Millar (1975), also using a primary letter matching task examined the possibility of a limitation occurring during encoding. Millar (1975) assessed the capacity demand of encoding by impairment in performance on a secondary probe detection task at the moment of encoding the primary

task. Millar concurred with Comstock (1973)

arguing that in the two experiments by Posner and Boies upon which the conclusions of memory processes were based, different warning and interstimulus intervals were used. To conclude that memory processes did not require processing capacity provided subjects had one second between items was unacceptable, the effect able to be attributed to the different length of warning intervals.

The assumption of Millar's study was that the individual had a finite capacity pool of processing resources which could be allocated, according to task demands, to particular stages in information processing (Moray, 1967; Kahneman, 1973). Letter-match stimuli were presented by two Nixie tubes mounted together inside a two-field tachistoscope, the total display size being five cm square and viewed through the eyepiece of the tachistoscope at a distance of approximately 100 cm. Physical match letters were drawn from the set A to M (omitting I) and were in uppercase form. Upside-down match letters were drawn from the same set, also in uppercase form, but omitting I and H. Response buttons for the letter-match were operated by the index and middle fingers of subject's dominant hand with the response stopping an electronic timer which had been triggered by the presentation of the first letter. The auditory probe was a 1000 cps, 100 msec. tone of approximately 70 dB presented by a loudspeaker mounted roughly

50 cm from subject's left ear. The visual probe was a 100 msec. flash of light generated by one of the tachistoscope's lamps and masked so as to give a stimulus form measuring 5 cm by 0.6 cm presented immediately above the letter display tubes. Response to the probe was a button press by the index finger of the non-dominant hand which stopped another timer which had been triggered by the probe onset. By increasing the level of difficulty of the encoding stage of the primary task, letter matching, so as to saturate available capacity, the encoding process was shown to require processing capacity through interference with the secondary probe task. These research findings, using essentially the same design, supported Comstock's (1973) findings. This view refuted the findings of Posner and Boies (1971) and the position advocating that memory contact and retrieval do not require access to processing capacity demands as purported by Keele (1970, 1972, 1973).

Levels of Processing

It is evident there is a lack of consensus on the relative processing demands of both retrieval and encoding operations. An explanation which viewed the processing functions to be at different levels was proposed by Craik and Lockhart (1972). A necessary consideration to the retrieval of any information, whether it be

motor, verbal or pictorial, is the formation of a memory trace or representation. Rather than delineate between short term and long term memory traces, Craik and Lockhart suggested the memory trace was based on the qualitative nature of stimulus encoding operations. After encoding, persistence of the memory trace is based on the depth to which the stimuli have been perceptually analyzed. Two types of perceptual coding were distinguished. Type I, or maintenance coding, was a function of the amount of rehearsal or repetition and merely prolongs the availability of the item without leading to the formation of a more permanent memory trace. Type II, or elaboration coding, was a function of the depth of processing and related to the memory trace strength as it can lead to changes in the internal representation of the stimulus.

Juola, Taylor, and Young (1974) introduced a "related levels of processing" interpretation. A study was conducted to examine recognition memory for words and pictures over varied lags between presentations of the items. A recognition model which assumed successive encoding, decision, and response stages was the basis of the interpretation of the results. The analysis indicated that stimulus form (word or pictures) and lag affected encoding processes similarly but the decision stages was influenced by the stimulus form. It was considered that the decision to respond was based on the familiarity value derived from

the conceptual code of the test item. However, the data of a second experiment indicated that memory for the stimulus form may also be used in the decision process. When this occurred, the decision occurred during the reconstruction of the perceptual code of the test item rather than during memory search for familiarity based on the conceptual code. In the instance where the decision is synonymous to the encoding, the subject was believed to be relying on the perceptual analysis for the decision. From the data, these researchers postulated that information is coded either perceptually or conceptually. The perceptual code was considered to be a primitive analysis of the physical characteristics of the stimulus. Beyond this initial level, information may be coded conceptually, with the material encoded being subjected to a semantic interpretation and assigned to a distinctive category.

Lockhart, Craik, and Jacoby (1975) modified the levels of processing model proposed in 1972 with Type I and Type II perceptual analysis being viewed as a continuum, with encoded stimuli being processed at three possible depths or levels of processing--physical, phonemic, and semantic. Rehearsal or repetition could be at any level with this function being termed the spread of processing. The persistence of the memory trace depended on both the depth and spread of processing. The deeper the level at which an event is encoded or the more elaborate the

processing within a level, the more persistent and richer the trace. Memory retrieval involving the scanning of recent traces or the guided reconstruction of an event in the perceptual/cognitive system was determined by the spread and level of processing.

Chabot, Millar, and Juola (1976) examined the relationship between the depth of processing and stimulus repetitions as representative of the spread of processing. Several levels of processing were defined involving a) physically identical items, b) physically different but same-name items, c) different items from the same semantic category, and d) items from different categories. Words and pictures were used as stimuli and, as would be predicted by the levels of processing model, the deeper the level of processing (e.g., semantic) the longer the categorization response time. Increasing the repetitions from one to five presentations led to a decrease in response times. Furthermore, distributed repetitions cause a significant increase in recall probability of items which was interpreted as evidence of the possibility of formation of a stronger memory trace at any level of processing. Hence, the data were supportive of a "depth of processing" approach to memory processes.

The Problem

Investigations into the attention demands of processing

movement information cannot but add to the understanding of the nature and functional characteristics of the kinesthetic sensory system. Accordingly, the kinesthetic modality was employed with inputs and outputs being achieved via the motor system.

The basic question to answer was whether the process of memory retrieval required attention. The motivation for the study was the notion that memory contact of two sources of information simultaneously was cited as evidence that memory retrieval does not require attention.

To isolate retrieval it was necessary to delineate between the memory processes of encoding, retrieval and response execution. By doing this, it was also possible to assess the relative demands of each of the processes with respect to kinesthetic sensory information. The divided attention paradigm has been used extensively in verbal research and was chosen for the present study. The attention demands of the memory processes were determined during a secondary task of motor shadowing which required continuous information processing throughout its presentation. A continuous task was deemed essential rather than a discrete secondary probe task as had often been used in previous research, particularly in studies of the encoding operation.

Researchers have suggested that the movement attributes of direction and distance are coded at different

levels with distance coded perceptually and direction coded conceptually. To examine this aspect, both direction and distance information were chosen as measures of secondary motor shadowing performance.

The rationale for the choice of the primary tasks was to assess the attention demands of the processing stages of encoding, retrieval and execution with regard to movement information. In encoding, subjects had to compare two movement lengths presented passively. In this condition, no output or execution was demanded. The subject essentially only had to perceive two movement lengths and compare them. The retrieval task (reproducing specific movement lengths which had been rehearsed) required the subject not only to retrieve the stored representation but to convert it into an overt reproduction. Hence, a condition whereby the subject was required to execute a similar movement but without regard to extent or direction enabled the attention demands of the actual overt movement and the retrieval from memory to be divided.

Based on findings of a number of experiments, several researchers have made inferences about memory processes which can only really provide tenuous conclusions. The comparison of the attention demands of each processing stage relative to one another was particularly meaningful considering that the memory processes were included within the

one experiment employing only the kinesthetic sensory system.

Justification of the Problem

Investigations of the processing of kinesthetic information necessary for motor responses will have far-reaching effects by providing the scientific knowledge necessary to understand the acquisition and retention of motor skills for human performance. It has been clearly established that man is limited in the amount of information which can be processed. Therefore, any determination of where processing limitations are will enable those responsible for the teaching of motor skills to ensure that these particular stages are not overloaded. Appropriate adjustments may then be provided to facilitate the effectiveness of information processing at this stage. Should the memory retrieval stage in processing of kinesthetic information require attention and involve distinct search and recovery processes (as is evidenced in the verbal domain) then studies providing the most minute knowledge of this process in the motor system will commence, the foundation from which the empirical knowledge will be derived. However, should the retrieval stage not be attention demanding, as Keele (1973) suggested, then it will be apparent that the processing of

kinesthetic sensory information does not parallel that of verbal sensory information and therefore research should be guided toward an understanding of the unique nature of processing kinesthetic information.

Purpose

The purpose was to determine if the retrieval of kinesthetic sensory information, as measured by recall from long-term memory, requires attention.

As it was necessary to separate retrieval from encoding and response execution it was possible to assess the relative attention demands of encoding and response execution with respect to solely kinesthetic sensory information.

Hypotheses to Confirm that Retrieval from Memory Requires Attention

1. The performance of motor shadowing while retrieving learned movement lengths in a known order of recall will be less accurate than motor shadowing when done while encoding a movement length.
2. The performance of motor shadowing while retrieving learned movement lengths in a known order of recall will be less accurate than motor shadowing when done during a response execution of a movement.

3. The performance of motor shadowing while retrieving learned movement lengths in an unknown order prior to recall will be less accurate than motor shadowing when done while encoding a movement length.
4. The performance of motor shadowing while retrieving learned movement lengths from memory in an unknown order prior to recall will be less accurate than motor shadowing during a response execution of a movement.
5. The performance of encoding a movement length while motor shadowing will be as accurate as when the encoding of the movement length is done alone
6. The time taken for response execution of a movement stop while motor shadowing will be the same as when response execution of movement is done alone.
7. The performance of retrieving of movement lengths from memory in a known order of recall while simultaneously motor shadowing will be as accurate as when the movement lengths are retrieved alone.
8. The performance of retrieving movement lengths from memory in an unknown order prior to recall while simultaneously motor shadowing will be as accurate as when the movement lengths are retrieved alone.
9. The performance of motor shadowing while simultaneously

retrieving learned movement lengths from memory in a known order of recall will be more accurate than motor shadowing while simultaneously retrieving learned movement lengths from memory in an unknown order prior to recall.

CHAPTER III

METHODOLOGY

Subjects

Thirty right-handed, right-footed volunteer Introductory Psychology university students (fifteen male, fifteen female) served as subjects. All were experimentally naive. The mean age was twenty-one years, three months with a standard deviation of three years, ten months. Each subject participated in nine experimental conditions.

Apparatus

Kinesthetic Sensory Apparatus

The apparatus used was identical for all trials within each experimental condition and is illustrated in Figure 1. It consists of two pantographs [A1] and [A2] each secured to the same twelve-inch square metal frame which allows movement on both ends of each pantograph within a circumference range of 81.28 centimeters. Handles are attached to the movable ends of each pantograph. Each handle links the subject's movement with that of the experimenters in a one-to-one correspondence. A roll of 40-weight paper [B], 60 centimeters in width, is suspended by a metal rod [C], 75 centimeters in length. The paper

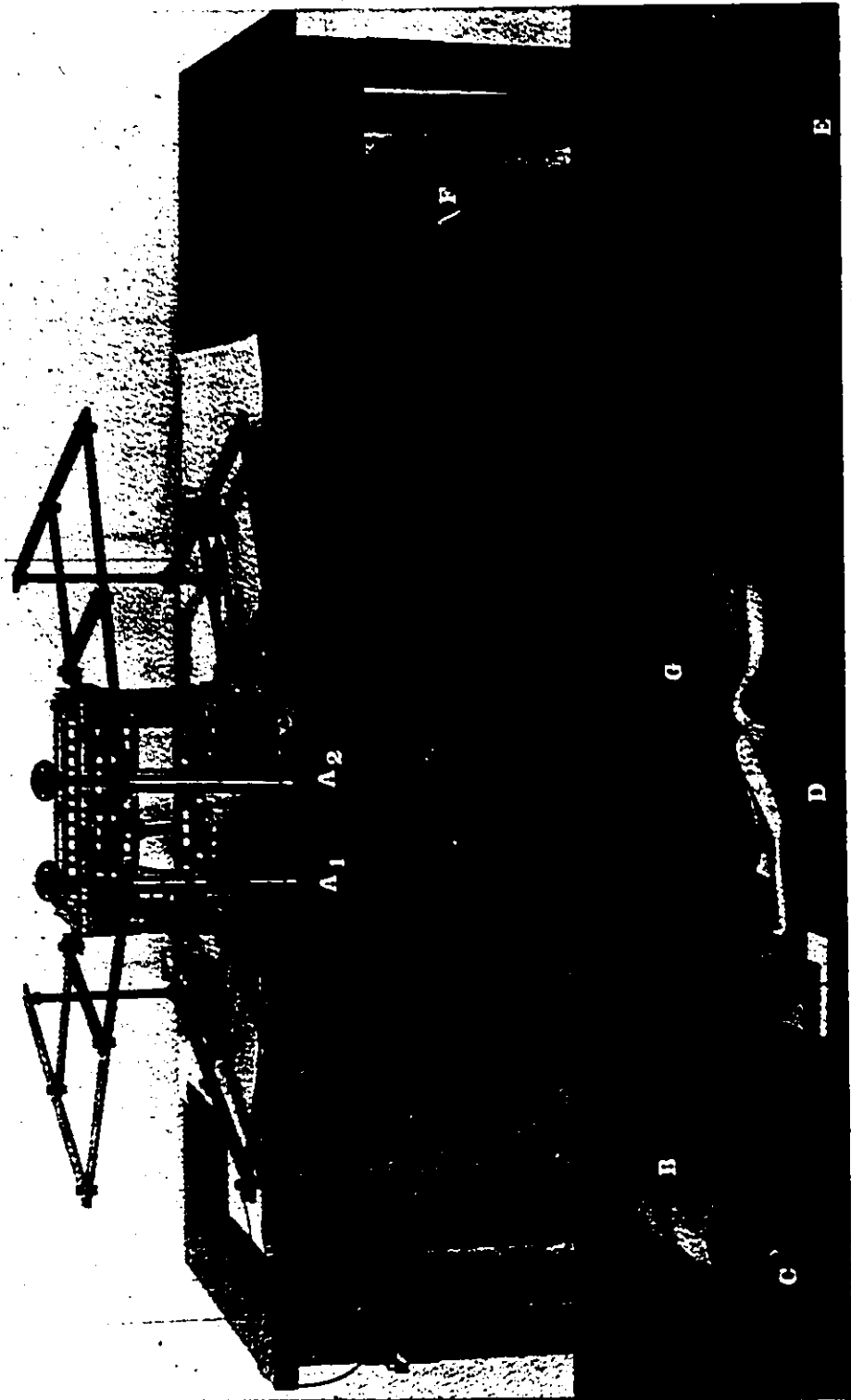


Figure 1 Kinesthetic Sensory Apparatus

extends over a metal baseboard [D], 121.92 centimeters wide. A second metal roll [E], 75 centimeters in length, anchors the paper on the metal baseboard. A crank is attached to a third metal rod [F] on which the paper is connected. This permits the paper to be rolled between trials. The right foot of the subject was fitted to a plywood footpiece [G] in which a magic marker was secured. The subject had full control of the foot when moving.

Movement of the left pantograph was guided by two forty centimeter metal runners [H₁] and [H₂] either side of the attached ending. Figure 2 depicts this portion of the apparatus viewed from the experimenter's side. On the outside of the right runner, a twenty-five centimeter length of wood [I] covered by a copper sheet was secured to the table. The copper was separated into three seven centimeter segments. A circuit was established between the ending of the left handle, the copper sheets and a microswitch [J] connected to three millisecond timers. This enabled the time of movements to be measured in three time periods during the course of the movement. A thirty centimeter metal rule [K] was secured to the left metal runner to enable the length of movement to be measured by reference to a pointer [L] attached to the left pantograph. A microswitch [M] which was placed against the end of the left handle and in circuit with a millisecond timer was used to time movements. Another

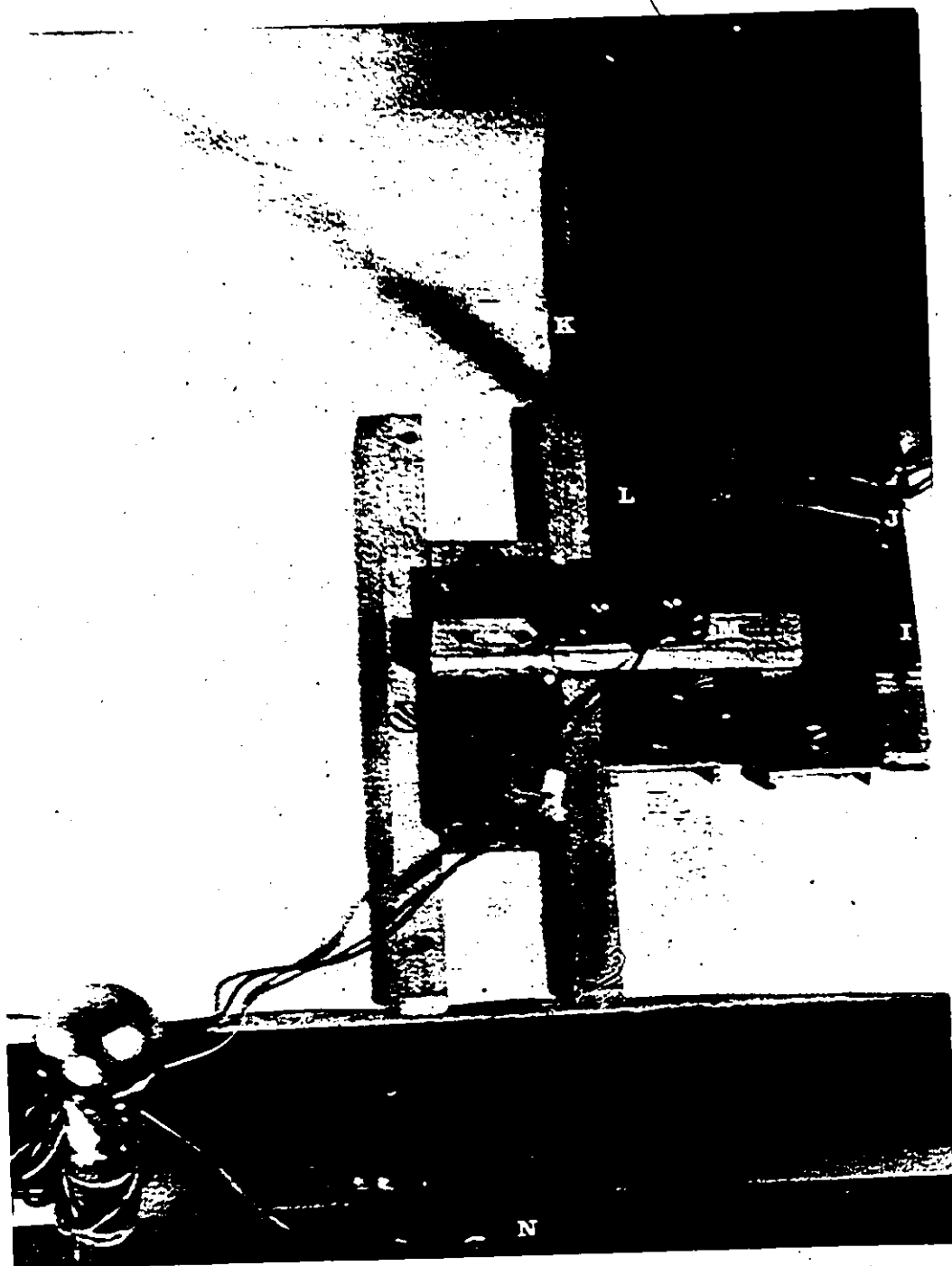


Figure 2 Ending of left pantograph with measurement equipment. (Viewed from experimenter's side).

microswitch [N] could be depressed by the experimenter on the completion of the movement. The experimental situation with the subject and the two experimenters is illustrated in Figure 3.

Experimental Design

The design was a 2x9 factorial design with repeated measures on the last factor. The conditions within the second factor were:

Condition 1	Encoding
Condition 2	Cued retrieval
Condition 3	Non-cued retrieval
Condition 4	Response execution
Condition 5	Motor shadowing alone
Condition 6	Motor shadowing and encoding
Condition 7	Motor shadowing and cued retrieval
Condition 8	Motor shadowing and non-cued retrieval
Condition 9	Motor shadowing and response execution.

Conditions 1-4 and 5-9 were systematically rotated independently across males and females as outlined in

Appendix D.

Independent Variables

There were two independent variables in the experimental design, sex and the number of tasks each with two levels. For the second independent variable, the number of tasks to be performed concurrently, the two levels were--

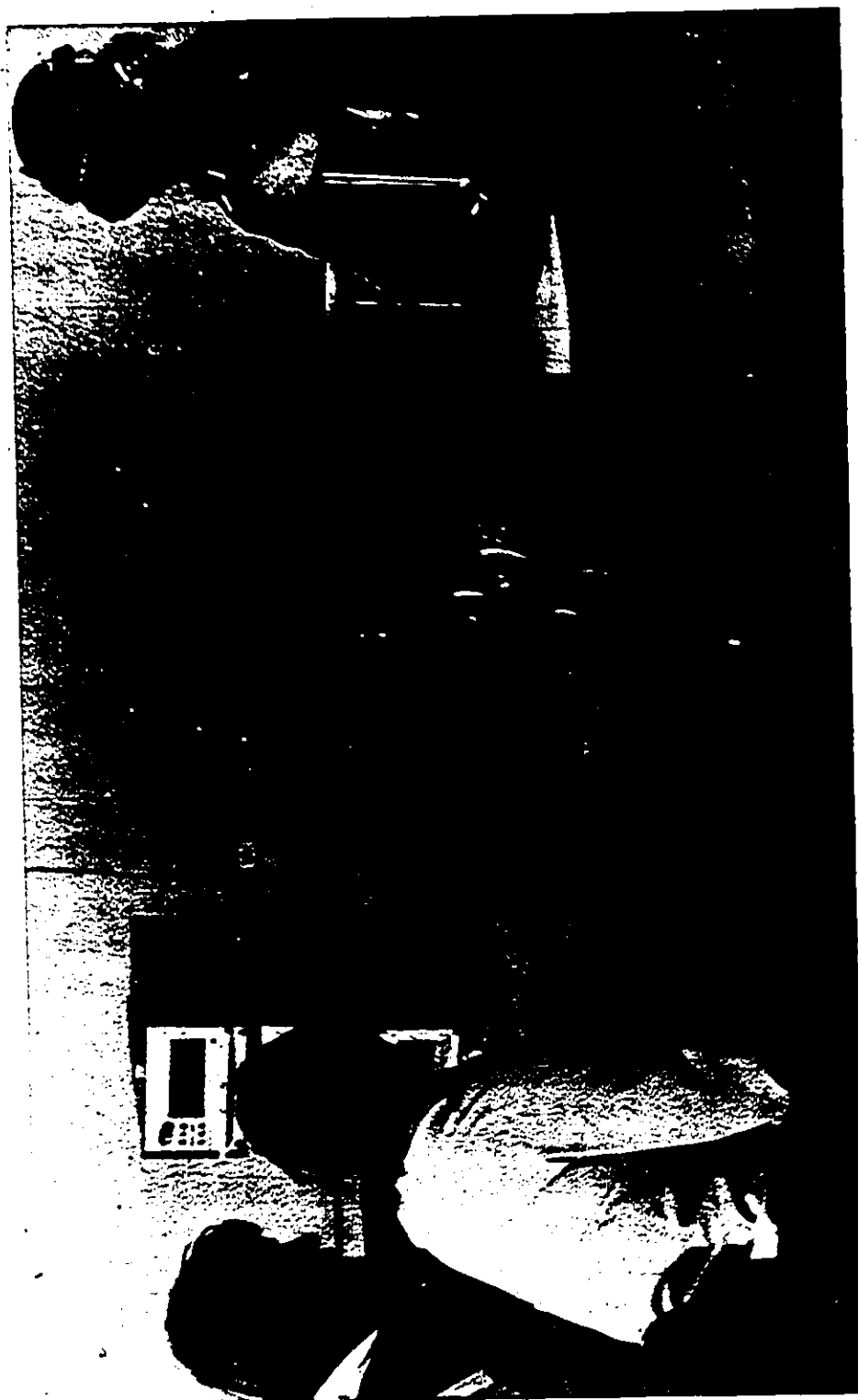


Figure 3 Kinesthetic Sensory Apparatus with the subject and the two experimenters.

single task and dual task situations. In the single task conditions, which all served as baseline standards for comparing the dual task performances, there were five sub-levels: (a) encoding, (b) cued retrieval, (c) non-cued retrieval, (d) response execution, and (e) motor shadowing. The dual task conditions involved four sub-levels of motor shadowing a kinesthetic sensory input to the right-hand together with (a) encoding, (b) cued retrieval, (c) non-cued retrieval, and (d) response execution.

Dependent Variables for Motor Shadowing

Three dependent variables were employed in the analysis of the shadowing of patterns of movement. The first dependent variable was the absolute error in the angles of the patterns shadowed by the subjects which deviated from the criterion angles presented by the experimenter. The mean absolute error of the length of lines between the angles which deviated from the criterion lengths presented by the experimenter was the second dependent variable. The third dependent variable was the number of direction changes missed as a percentage of the total number of direction changes presented. The four patterns which were used are located in Appendix B.

Control Measures of Encoding, Retrieval, and Response Execution

Encoding: The number of correct verbal responses of the 'same' or 'different' to the movement length presented by the experimenter during trials, as compared with a movement length presented prior to the trial in encoding, served as the control of encoding performance. Correct responses 'same' or 'different' were recorded to ensure that encoding performance in the single task conditions were comparable with encoding in the dual task conditions thereby establishing that subjects only devoted as much attention to motor shadowing as encoding permitted. On any trial where an incorrect response was given the trial was discounted and a further trial given.

Cued and non-cued retrieval: There was one control measure for retrieval of the length of movement--the absolute error of the length of movement recalled from the criterion length which had previously been learned. On all trials, subjects were required to be within an absolute deviation of 10% of the criterion length otherwise trials were not counted. This measurement was necessary to ensure that subjects only devoted as much attention to motor shadowing as the retrieval conditions permitted.

Response execution: The time taken for the left pantograph to transverse the distance moved to a stop

was measured in three time periods of seven centimeters each. The time taken on trials of single task condition were compared to those performances together with motor shadowing to ensure the response execution times were comparable under both conditions.

Procedures

The experiment consisted of approximately two fifty-minute sessions administered on two consecutive days. The first day was devoted to the learning phases while on the second day the testing phase was completed.

Learning Phase

This session consisted of teaching three movement lengths which had to be both recognized and recalled to a criterion standard to determine that the lengths were rehearsed into long-term memory for later retrieval.

Upon arrival at the laboratory the nature of the study and the procedures were explained in general terms. The subject was then required to wear goggles (to prevent visual information being available during the experiment) and guided into the laboratory and seated facing the kinesthetic sensory apparatus. Earphones were placed on the head and the purpose of the learning phase was explained. All experimental instructions were given through the earphones. During actual performance the earphones emitted

masking noise in order to prevent any auditory sensory information being available. One of three movement lengths to be learned--4, 9 and 13 centimeters, identified as lengths 1, 2 and 3 respectively--was presented to the left hand. After four presentations by the experimenter, the subject was required to reproduce the length and then remove the hand from the handle. Knowledge of results was provided by the experimenter to assist the subject in learning the length. The actual distance in millimeters was recorded on all trials. The subject continued practicing until the distance could be reproduced five consecutive times within an absolute deviation of 10% of the criterion distance. The times for four correct movement reproductions during learning were recorded to the nearest millisecond. Once the subject was able to reach the pre-established standard, the other two lengths were taught in the same manner. When it was considered the lengths had been learned, the experimenter randomly presented them for recognition. The subject was required to verbally respond as to which length was presented. Once the lengths could be identified, it was considered they had been learned and rehearsed into long-term memory. Prior to a five-minute break, the subject was given practice combining the lengths to be reproduced in one continuous motion, the total distance of the lengths being of interest. Once again, knowledge of results was

provided. During the break, subjects left the laboratory. Upon returning to the laboratory the footpiece was attached to the right foot and retention of lengths was tested.

Practice was then given until achievement of five consecutive reproductions within the 10% deviation. Once this was completed, practice was given shadowing with the right foot geometric patterns presented to the right hand, although at no time were the patterns to be used in the experimental phase presented. The subject was instructed to slide the whole foot and concentrate on the direction of the movement, the distance and change direction at the same angles with the right foot as was being presented to the right hand. At the completion of presentation of three patterns, the subject was permitted to leave and reported back to the laboratory at the same time the following day.

Testing Phase

When the subject returned the following day, he was again seated facing the kinesthetic sensory apparatus, the footpiece attached to the right foot. The retention of the three lengths learned the previous day was then tested. When the subject did not achieve the designated standard of 10% deviation from the designated length, relearning occurred--the procedures the same as for the previous day.

Following any necessary rehearsal, the testing phase was commenced. The instructions and the procedures within each of the nine conditions was explained on the ear-phones from a pre-recorded tape. Before all conditions commenced, the subject was required to re-explain what was to happen to ensure the instructions were completely understood. The instructions which preceded each experimental condition are included in Appendix A. The subject was instructed in the dual task conditions, it was imperative to only give as much attention to the motor shadowing task as the encoding, retrieval and response execution movement tasks permitted. This technique was used to determine the sensitivity of the motor shadowing task to the information processing demands of the above mentioned primary movement tasks.

Condition 1 - Encoding

This condition consisted of four trials necessitating a 'same' or 'different' verbal response--the correct response on two trials being the 'same' and two being 'different.' Following the instructions and any clarification, one of the three learned lengths was presented to the left hand, the subject having to encode the distance. The left hand was then removed from the handle. The signal to replace the hand was the masking noise being turned off and on. The experimenter then presented

another of the learned lengths. On the completion of the second presentation, the subject replaced the hands on the lap and then gave the verbal response 'same' or 'different' based on comparison of the two lengths presented. The four pairs of movements which were presented are outlined in Appendix E.

Condition 2 - Cued retrieval

Following the instructions, the subject assumed the ready position with both hands on the pantograph handles. Then the number(s) of the length(s) to be retrieved were given on the earphones. The distance(s) were then recalled by moving the left pantograph forward until the subject considered the criterion length was reproduced. Hands were then replaced on the lap to await the number(s) corresponding to the next movement length to be reproduced. The movement times were recorded. The four lengths to be retrieved and the order of trials are outlined in Appendix E.

Condition 3 - Non-cued retrieval

Following the instructions, the subject placed both hands on the pantograph handles. The left hand was then very slowly moved forward. As soon as the experimenter detected movement of the left pantograph the number(s) corresponding to the length(s) to be reproduced was given

over the earphones. The subject continued movement forward until it was considered the designated length was reproduced. The distance travelled prior to the number(s) being given was to be included as part of the overall length of movement. The movement times were recorded. The four lengths to be retrieved and the order of trials are outlined in Appendix E.

Condition 4 - Response execution

Following the instructions, the commencement of the first trial was indicated by the start of the masking noise on the earphones. The subject then pushed the left pantograph forward slowly and smoothly a distance of twenty-one centimeters the movement through the metal runners terminated by a wooden stopper. Between trials the subject removed the left hand and the experimenter moved the left pantograph back ready for the next trial.

At the completion of the first four conditions the subject was given a two-minute rest period.

Condition 5 - Motor shadowing

The four trials by all subjects in this condition involved single task presentation of motor shadowing of movement presented to the right hand. The subject shadowed the movement patterns with the right foot, adhering to perceived length of lines, direction of movement.

and angles of any direction changes. Four patterns of movement, one for each trial, were presented to all subjects in the order outlined in Appendix E. Each pattern presentation was approximately ten seconds with an inter-trial interval of fifteen seconds, during which time the paper and the pattern were changed.

A millimeter scale on each pattern enabled the experimenter to determine where the presentation of movement was concluded in the remaining dual task conditions. This was necessary as it was possible, and usually the case, that the entire pattern presentation was not completed prior to the completion of the movement task with the left hand.

Condition 6 - Motor shadowing and encoding

The commencement of the four trials in this condition followed the pre-recorded instructions. On each trial, the subject was presented one of the three previously learned movement lengths, the distance of the movement being encoded, the hand removed from the left handle following the cessation of the movement. The masking noise was turned off and on which indicated to resume the ready position with the hand replaced. A pattern was then presented to the right hand to be shadowed by the right foot, while a second learned movement length was simultaneously presented to the left hand. The presenta-

tion of the pattern to the right hand was always completed at the same time as the completion of the presentation of the second movement length. With the cessation of movement to the left hand, the subject remained steady, the foot held in a stationary position. The response 'same' or 'different' was then given, based on the comparison of the two lengths presented to the left hand. The experimenter then lifted the foot to enable the paper to be rolled for the next trial--the left pantograph being placed back in position. The lengths of movements and the order of presentation are outlined in Appendix E. The order of presentation of the patterns are outlined in Appendix E.

Condition 7 - Motor shadowing and cued retrieval

The number(s) of length(s) to be retrieved were given prior to each trial. A pattern was presented to the right hand to be shadowed, while the subject simultaneously recalled the length(s) denoted by the number(s) of the movement length(s) given on the earphones. Presentation of the pattern was ceased upon completion of the left hand movement by the subject. The length(s) to be recalled in each of the four trials and the order of the patterns are outlined in Appendix E.

Condition 8 - Motor shadowing and non-cued retrieval

On trials in this condition, following the commence-

ment of the masking noise, the subject placed both hands on the handles and when ready commenced movement of the left pantograph slowly and smoothly forward. As soon as the experimenter detected movement the number(s) of the length(s) to be reproduced were given. The subject continued to move the left hand forward until it was considered the distance corresponding to the number(s) had been reproduced. As soon as the subject commenced movement of the left hand the second experimenter presented a pattern to the right hand to be shadowed. The presentation of the pattern was ceased upon completion of the left hand movement by the subject. The lengths to be recalled in each of the four trials and the order of the patterns are outlined in Appendix E.

Condition 9 - Motor shadowing and response execution

Following the instructions and any necessary explanation, the subject placed both hands on the pantograph handles and moved the left pantograph slowly and smoothly the same as in Condition 4. As soon as the movement was commenced, the second experimenter presented a pattern to the right hand to be shadowed with the right foot. When the movement of the left hand was stopped, the presentation of movement to the right hand was terminated.

Data Analysis

1. A series of two factor analyses of variances (sex x tasks) with repeated measures on the last factor were computed in order to determine the differences in motor shadowing performances as related to sex. These would determine if there were differences between sexes in respect to the demands of the various processing stages of encoding retrieval and response execution.
2. Single factor analyses of variances with repeated measures were computed for the primary tasks when combined with motor shadowing. For these analyses the sex variable data was pooled.
3. A two factor analyses of variance (condition x segment) was computed to compare response execution times over three, seven centimeter segments both alone and when combined with motor shadowing.
4. A series of one-way analyses of variance (number of items) were computed for the number of lengths retrieved from memory in cued and non-cued retrieval.
5. Scheffe (S) post hoc comparisons were calculated for significant motor shadowing performances for all three dependent variables.
6. Scheffe tables were drawn for all motor shadowing main effects.
7. Graphs were drawn for each dependent variable for

shadowing performances alone and together with the primary tasks.

8. The $\alpha = .05$ level of confidence was accepted for all experimental analyses.

CHAPTER IV

RESULTS

There have been numerous explanations forwarded to account for man's limitations in processing information derived from the sensory receptors. Subsequent to the arrival at the receptors, stages of encoding, retrieval from memory and response execution have been delineated. It has been suggested that some stages in processing may not require attention and thus can be discounted as a possible source of a limitation in processing. Several researchers consider the bottleneck to be at the response execution stage advocating encoding and retrieval of information to be automatic and non-attentive processes.

The experimental design in the present study enabled the stages of encoding, retrieval and response execution to be isolated and the attention demands of each to be assessed during the processing of kinesthetic information. The design consisted of two phases, the first a training phase was devoted to learning three movement lengths of 4, 9, and 13 centimeters. The mean number of trials for subjects to learn the lengths (to within ten percent absolute deviation of the criterion length) were: 14.76, 8.79, and 11.2. respectively. Following a five-minute

retention interval, during the learning phase, the mean number of trials to reach the criterion were 10.76, 6.79, and 7.93. After a twenty-four hour retention period, the mean number of trials to reach the criterion were 11.48, 8.03, and 7.93 for 4, 9, and 13 centimeters, respectively. Subsequent to the reattainment of the necessary standard, on the second day the second phase with the experimental conditions was administered.

Guaranteed Primary Task Controls

Four primary tasks were chosen explicitly to assess the attention demands of the following processing stages: encoding, retrieval and response execution. Two primary tasks were selected to examine two different levels of retrieval of information from memory. Each task was ~~per-~~formed separately and then combined with the secondary task of motor shadowing. Controls were established to guarantee that each of the primary tasks, received the allocation of attention it demanded, and that only remaining processing capacity could be devoted to the secondary task of motor shadowing.

Encoding

The encoding task involved two of the movement lengths previously learned being presented successively to the

left hand. The subject was required to respond 'same' or 'different' based on the comparison of the two lengths presented. Four trials were given and on any trial where an incorrect response was given, a further trial was included. When combined with motor shadowing, on the presentation of the second movement length to the left hand, movement was also presented to the right hand to be shadowed with the right foot. The subject shadowed this movement while attempting to provide a correct response in the comparison of the two lengths presented to the left hand. The mean number of trials for subjects to correctly identify the lengths in encoding when performed with motor shadowing was 5.2 trials with a standard deviation of 1.3. Based on 50% correct responses on each trial, had the subject been guessing the mean number of trials to identify the lengths correctly would have been seven. Therefore, it can be asserted that the subjects were primarily encoding the distance presented and were only devoting additional capacity to the secondary motor shadowing task.

Cued and non-cued retrieval

Retrieval from memory required the subject to reproduce the movement lengths previously learned by moving the left handle forward. In cued retrieval, the number(s) corresponding to the movement length(s) to be retrieved

from memory were known prior to the commencement of the trial. In non-cued retrieval, the number(s) corresponding to the movement length(s) to be retrieved from memory were not given until the subject commenced movement of the left hand. In both forms of retrieval the movement lengths when retrieved while motor shadowing were required to be within 10% of the criterion length. Consequently, in retrieval and motor shadowing conditions, motor shadowing performances were not accepted unless the retrieval performance was within this criterion standard.

Response execution

In the response execution task, the subject was required to move the left hand slowly and smoothly forward twenty-one centimeters until the movement was stopped. To ensure the movement was comparable when combined with motor shadowing as when performed alone, the speed of movement was timed for three seven-centimeter segments. Any movement time when performed with motor shadowing which deviated markedly from performances alone was discounted and a further trial given. A 2 x 3 analysis of variance (task x condition) was computed and is presented in Table 1.

The main effect of single versus dual task performance was not significantly different, $F(1,58) = 0.18$ $p > .05$. The mean movement time for all subjects across the three

Table 1
Summary Table for the Analysis of Variance for the Response
Execution Times Alone and Together with Motor Shadowing
for Three Equal Movement Lengths

Source	SS	df	MS	F
Between Subjects	173.97	59		
'A' Main Effects	0.54	1	0.54	0.18
Subjects Within Groups	173.43	58	2.99	
Within Subjects	45.14	120		
'B' Main Effects	15.59	2	7.79	30.93*
'AB' Interaction	0.33	2	0.16	0.64 \bar{a}
'B' x Subjects Within Groups	29.23	116	0.25	

* $p < .05$

seven-centimeter segments were 1.93, 2.63, and 2.46 seconds respectively for response execution alone and 1.81, 2.43, and 2.46 with motor shadowing. There was a significant main effect of movement segment, $F_{(2,120)} = 30.93$ $p < .05$, while there was no significant interaction, $F_{(2,116)} = 0.64$ $p > .05$. Figure 4 graphically presents the relationship of the movement time to the segment of the movement and the single versus dual task conditions. The movement times indicated subjects did not execute the movement slowly and smoothly. A ballistic initiation was followed by a slowing down in the middle segment of the movement and a slight increase in speed in the final segment when movement was executed alone. However, as there was no difference in the response execution movement times when performed alone and with motor shadowing, it may be accepted that the movements made were the same.

By implementing the aforementioned controls, it was possible to ensure that subjects only devoted as much attention to the secondary motor shadowing task as the encoding, cued retrieval, non-cued retrieval, and response execution tasks permitted. This was necessary to guarantee the primary encoding, retrieval or response execution task gained initial access to the available central processing capacity. Any remaining capacity could be devoted to the secondary motor shadowing task and the relative demands could then be determined as a function of the demands of

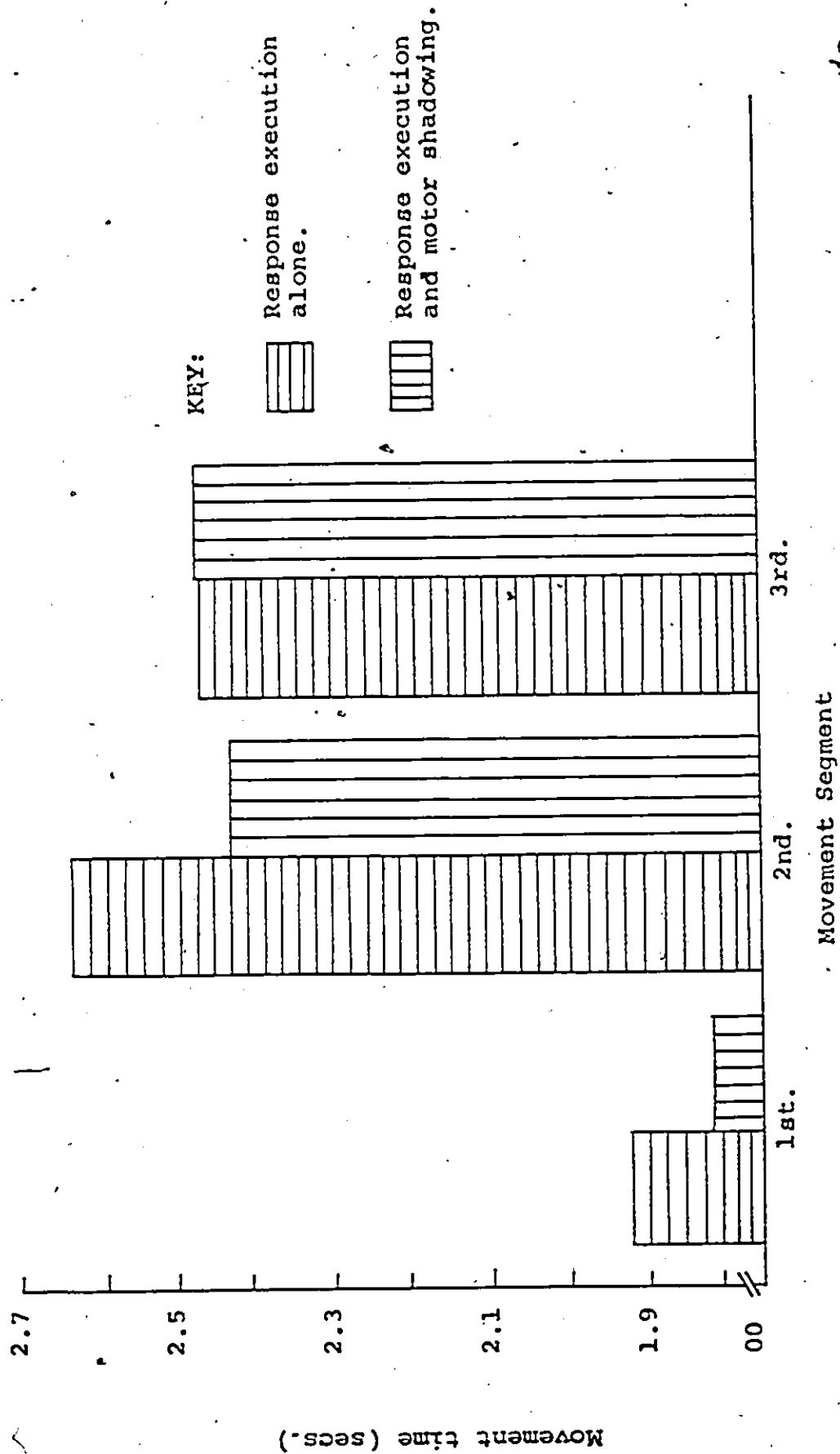


Figure 4 Time of movements in response execution measured in three seven centimeter segments, alone and together with motor shadowing.

the processing stages being investigated.

Secondary Motor Shadowing Performances

Since all the controls were met the relative demands of each secondary motor shadowing performance in the dual situation was evaluated against a baseline performance of motor shadowing alone. Three dependent measures were computed to determine motor shadowing performance. The results are presented separately for each of the dependent variables; mean absolute error of the angles, mean absolute error of the lengths of lines drawn between angles, and the percent of direction changes missed. All the ANOVA tables computed for motor shadowing performances are located in Appendix C.

A series of 2 x 5 analyses of variances (sex x conditions) with repeated measures on the last factor for each of the dependent variables were calculated. There was no significant main effect of sex for mean absolute error of angles, $F_{(1,28)} = 0.59$ $p > .05$; mean absolute error of lengths, $F_{(1,28)} = 0.02$ $p > .05$; and number of direction changes missed, $F_{(1,28)} = 0.65$ $p > .05$.

As there was no significant sex effect for each of the three dependent measures of motor shadowing performance, the sex variable data were pooled and analyzed using 1 x 5 analyses of variances with repeated measures.

The Scheffe (S) method of multiple comparisons was then applied to compare each of the motor shadowing conditions separately for each dependent variable.

Mean absolute error of
angles shadowed

There was a significant difference between each of the motor shadowing conditions, $F_{(4,116)} = 36.81$ $p < .05$. The mean absolute error in degrees of angles shadowed for motor shadowing alone, motor shadowing and response execution, motor shadowing and encoding, motor shadowing and cued retrieval, and motor shadowing and non-cued retrieval were: 22.67, 35.50, 38.87, 47.32, and 58.80 respectively, which is graphically depicted in Figure 5. The Scheffe (S) values for each individual comparison of the mean absolute error of the angles in motor shadowing are presented in Table 2. Motor shadowing performance alone was significantly different from motor shadowing when combined with all primary tasks. The mean difference in degrees between motor shadowing alone, and (a) response execution, (b) encoding, (c) cued retrieval, and (d) non-cued retrieval was 12.83, 16.20, 24.65, and 36.13.

Motor shadowing and response execution was significantly different from both cued and non-cued retrieval when combined with motor shadowing with the mean absolute error in degrees in response execution being 11.82 and

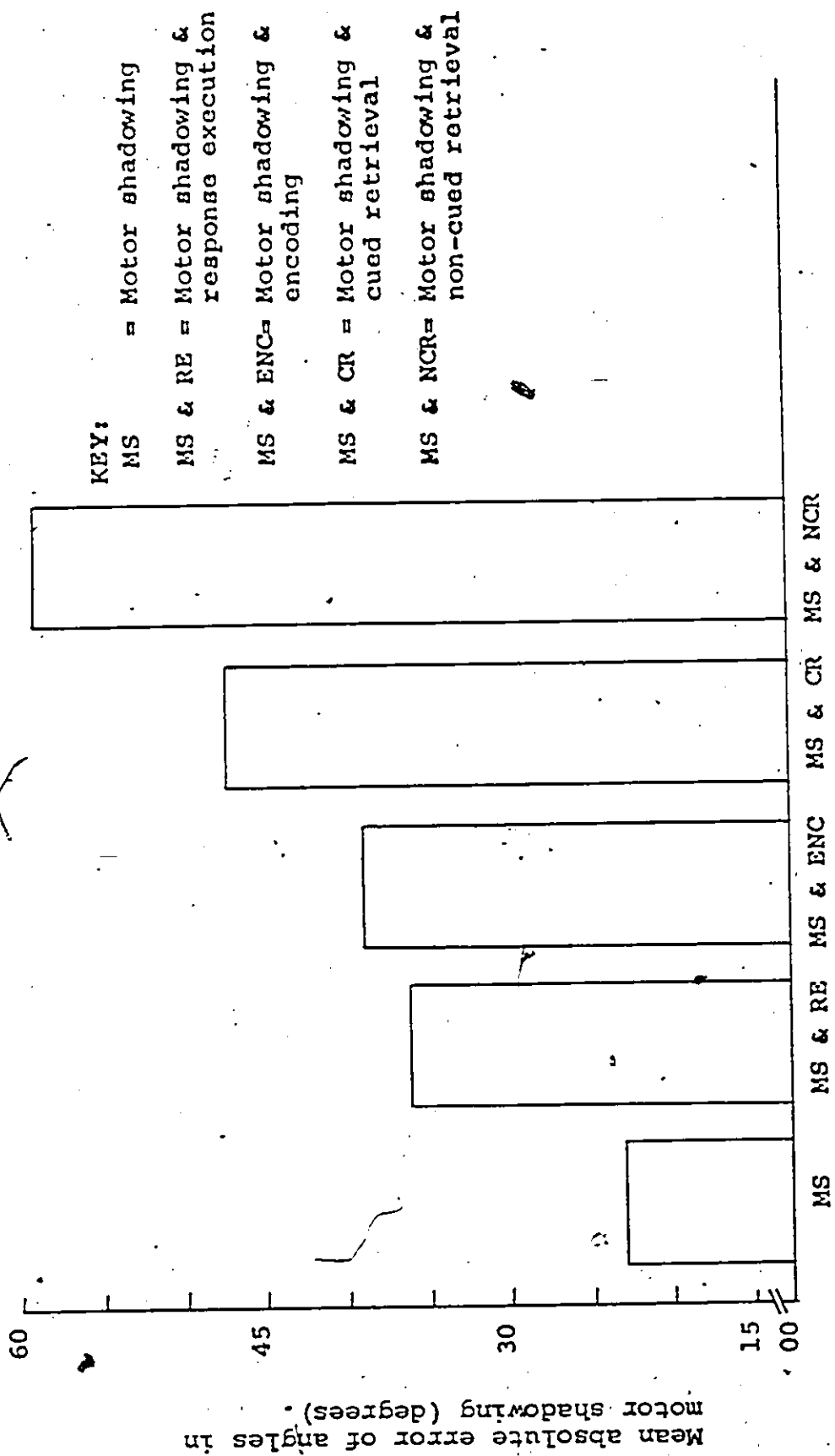


Figure 5 Mean absolute error in degrees of angles in motor shadowing for single and dual task conditions.

Table 2

Comparison of the Mean Absolute Error of the Angles in Motor Shadowing When Performed Alone and With Response Execution, Encoding, Cued Retrieval and Non-cued Retrieval Using the

Scheffe (S) Post Hoc Comparison Technique

Experimental Condition	Motor Shadowing Alone	Motor Shadowing and Response Execution	Motor Shadowing and Encoding	Motor Shadowing and Cued Retrieval	Motor Shadowing and Non-cued Retrieval
Mean Absolute Error in Degrees	22.67°	35.50	38.87	47.32	58.80
Motor Shadowing Alone	-	4.08*	5.16*	7.84*	11.50*
Motor Shadowing and Response Execution		-	1.07	3.76*	7.42*
Motor Shadowing and Encoding			-	2.69	6.34*
Motor Shadowing and Cued Retrieval				-	3.65*
Motor Shadowing and Non-cued Retrieval					-

Required $S(4,116) = 3.13$ $p < .05$

* $p < .05$

23.30 less, respectively.

As well as being significantly different from motor shadowing alone, motor shadowing and encoding was significantly different from motor shadowing and non-cued retrieval. The actual difference was 19.93 degrees.

Motor shadowing and cued retrieval was significantly different from all other primary tasks with the exception of motor shadowing and encoding, the difference between these two conditions was 8.45 degrees.

Motor shadowing performance when combined with non-cued retrieval was significantly less accurate than motor shadowing when performed together with all the other primary tasks. The mean absolute error of the angles of motor shadowing in non-cued retrieval was 23.30, 19.93, 11.48 degrees greater than for response execution, encoding and cued retrieval, respectively. Hence, it was apparent each of the processing stages of encoding, retrieval and response execution when combined with shadowing adversely affected the shadowing of the angles presented. Clearly, the greatest interference (58.80 degrees) was the situation in which the items to be retrieved from memory were not known prior to the actual retrieval situation. The extent of interference to secondary motor shadowing when comparing two movement lengths presented passively was of the same magnitude as was required to reproduce movement lengths known prior to the actual

retrieval situation. Furthermore, the comparison of the two movement lengths presented passively produced equal interference to secondary motor shadowing, as did movement which only required movement to a stop. However, the interference to motor shadowing caused when reproducing movement lengths, known prior to the actual reproduction, was significantly greater than executing a movement without regard to extent, corrections and termination of the movement.

Direction changes missed in motor shadowing

There was a significant difference between the motor shadowing conditions, $F(4,116) = 33.80$ $p < .05$ for the percent of direction changes missed. Table.3 contains the S values for each of the experimental conditions while the relationship of the percentage of directional changes missed to the experimental conditions is depicted in Figure 6. The percent of direction changes missed for motor shadowing alone, motor shadowing and response execution, motor shadowing and encoding, motor shadowing and cued retrieval, and motor shadowing and non-cued retrieval were: 0.00%, 11.63%, 15.27%, 33.27%, and 40.30%. The magnitude of direction changes missed in motor shadowing followed a similar pattern to the mean absolute error of the angles presented in motor shadowing. There

Table 3

Comparison of the Number of Direction Changes Missed in Motor Shadowing
When Performed Alone and With Response Execution, Encoding, Cued
Retrieval and Non-cued Retrieval Using the Scheffe (S)

Post Hoc Comparison Technique

Experimental Condition	Motor Shadowing Alone	Motor Shadowing and Response Execution	Motor Shadowing and Encoding	Motor Shadowing and Cued Retrieval	Motor Shadowing and Non-cued Retrieval
Percentage of Direction Changes Missed	00.00	11.63%	15.27%	33.27%	40.30%
Motor Shadowing Alone	-	2.80	3.72*	8.27*	10.04*
Motor Shadowing and Response Execution	-	-	0.92	5.47*	7.25*
Motor Shadowing and Encoding	-	-	-	4.55*	6.33*
Motor Shadowing and Cued Retrieval	-	-	-	-	1.78
Motor Shadowing and Non-cued Retrieval	-	-	-	-	-

Required $S(4,116) = 3.13$ $p < .05$

* $p < .05$

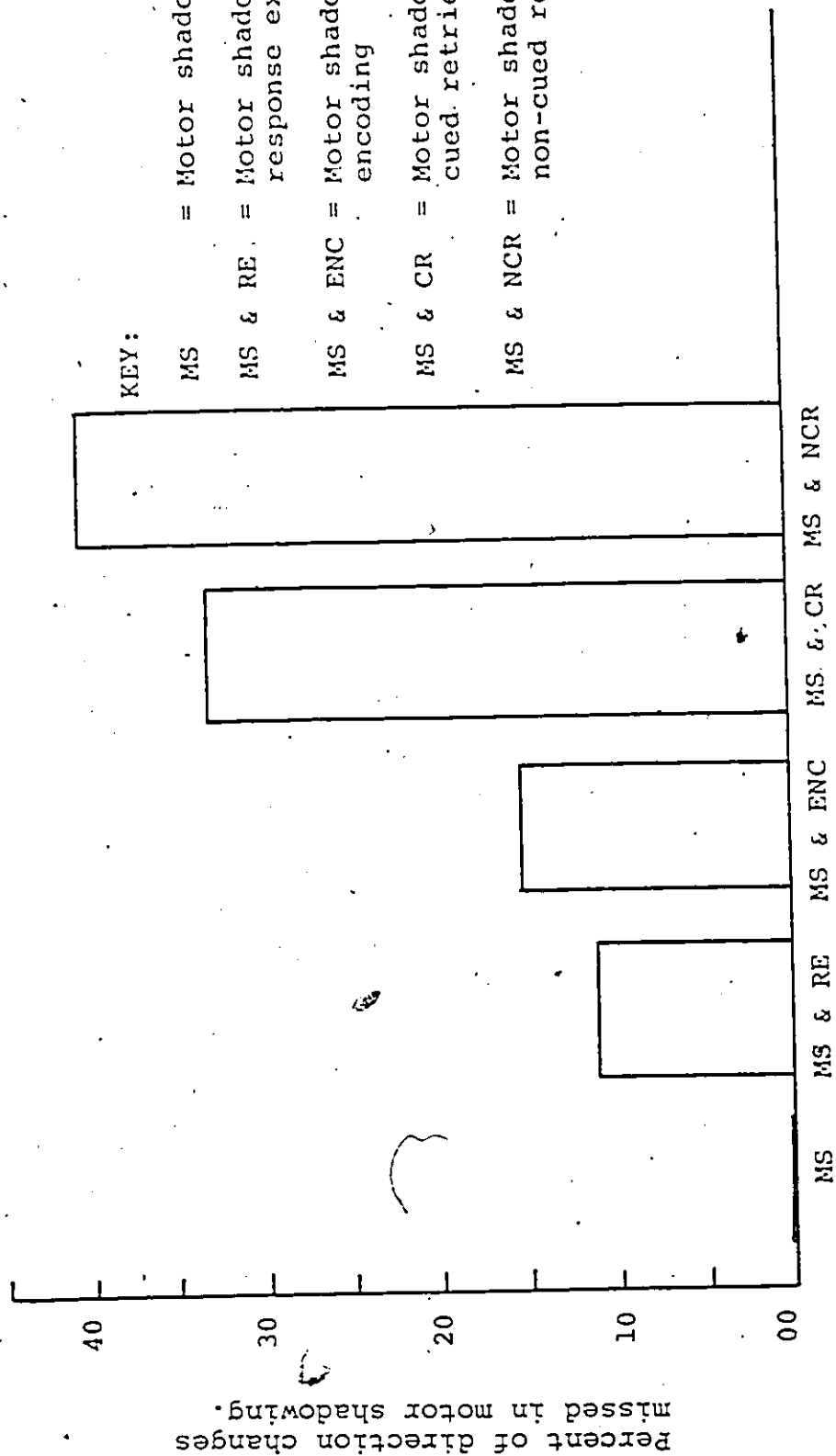


Figure 6 Percent of direction changes missed in motor shadowing for single and dual task conditions.

was a significant difference between motor shadowing alone compared to motor shadowing combined with encoding, cued, and non-cued retrieval. There were no direction changes missed in either response execution or motor shadowing alone. With respect to the number of direction changes presented, the greatest decrement in performance in the secondary motor shadowing task was the reproduction from memory of movement lengths not known prior to the actual retrieval performance. Furthermore, it was evident that each of the other processing tasks, except response execution, caused a significant decrement in motor shadowing as evidenced by the percent of direction changes missed for each primary task being significantly more than when motor shadowing was performed alone. Motor shadowing when combined with encoding resulted in the omission of 15.27% which was significantly less than when motor shadowing was combined with cued and non-cued retrieval. The differences from motor shadowing and encoding for each was 18.00 and 25.03 degrees. Motor shadowing and response execution resulted in a 3.64% increase in omission of direction changes than motor shadowing and encoding, although this difference was not significant, $S_{(4,116)} = 0.92$ $p > .05$. The tasks of identifying passive movement distances as 'same' or 'different' and executing a movement to a stop produced less interference to the shadowing of the direction changes than did cued and non-cued

retrieval of movements from memory. However, both did cause a significant decrement in performance as evidenced by the decrement of motor shadowing when compared to motor shadowing alone.

The difference of 7.03% of direction changes missed in motor shadowing when performed with cued as opposed to non-cued retrieval failed to reach significance, $S_{(4,116)} = 1.78$ $p > .05$. Unlike the mean absolute error of angles motor shadowed, the number of direction changes missed in motor shadowing when reproducing movement lengths was no more adversely affected by the lengths to be retrieved not being known prior to the actual retrieval performance.

Mean absolute error of lengths of
lines in motor shadowing

There was a significant difference between motor shadowing conditions, $F_{(4,116)} = 2.64$ $p < .05$. The mean absolute error of the length of lines for all subjects for motor shadowing alone, motor shadowing and response execution, motor shadowing and cued retrieval, and motor shadowing and non-cued retrieval were: 4.90, 6.12, 5.38, 5.29, and 5.72 centimeters. The relationship of the lengths of lines to the conditions of motor shadowing are illustrated in Figure 7 while S values for each condition are presented in Table 4. There was no significant differences of the lengths of lines in terms of the S values, $p > .05$.

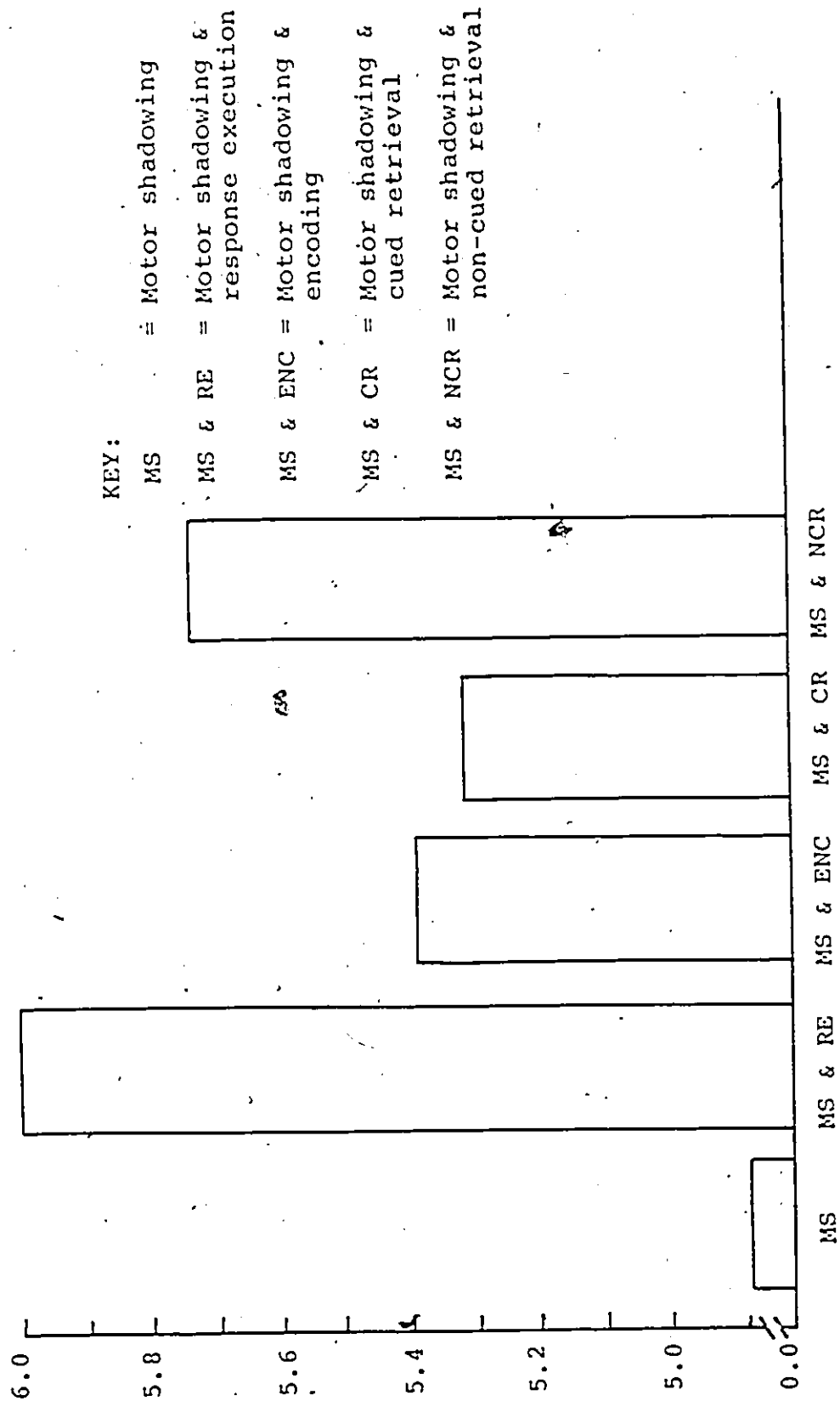


Figure 7 Mean absolute error in centimeters of lengths of lines in motor shadowing for single and dual task conditions.

Table 4

Comparison of the Mean Absolute Error of the Lengths in Motor Shadowing
When Performed Alone and With Response Execution, Encoding, Cued
Retrieval and Non-cued Retrieval Using the Scheffe (S)

Post Hoc Comparison Technique

Experimental Condition	Motor Shadowing Alone	Motor Shadowing and Response Execution	Motor Shadowing and Encoding	Motor Shadowing and Cued Retrieval	Motor Shadowing and Non-cued Retrieval
Mean Absolute Error Lengths in Centimeters	4.90	6.12	5.38	5.29	5.72
Motor Shadowing Alone	-	3.04	1.19	0.97	2.05
Motor Shadowing and Response Execution	-	-	1.85	2.07	0.99
Motor Shadowing and Encoding	-	-	-	0.22	0.86
Motor Shadowing and Cued Retrieval	-	-	-	-	1.08
Motor Shadowing and Non-cued Retrieval	-	-	-	-	-

Required $S(4,116) = 3.13$ $p < .05$

* $p < .05$

However, the difference of 1.22 centimeters between motor shadowing alone and motor shadowing and response execution reached significance, $S = 3.04$ $p < .10$. From the mean absolute error of the lengths in motor shadowing, it was obvious that subjects were unable to reproduce the movement lengths as presented in motor shadowing. This is a valid interpretation, particularly when the mean absolute error of the lengths in motor shadowing performances alone was approximately five centimeters which is half the mean absolute length of the movements presented.

Items in Retrieval

The retrieval of movement lengths from memory while motor shadowing was structured so that as ancillary information the effect of the number of items to be retrieved could be examined. There was no significant difference of motor shadowing with respect to the number of items in cued retrieval for neither the absolute error of angles, $F_{(3,87)} = 0.82$ $p > .05$ nor the mean absolute error of the lengths of lines, $F_{(3,87)} = 1.34$ $p > .05$. In non-cued retrieval the difference in motor shadowing with respect to length of lines failed to reach significance, $F_{(3,87)} = 1.25$ $p > .05$. However, there was a significant difference disclosed for the angles shadowed, $F_{(3,87)} = 3.86$ $p < .05$. Employing the Scheffe (S) test it was demonstrated that the only significant difference (18.18 degrees) was the

retrieval of the 13-centimeter movement length as opposed to the retrieval of all three movement lengths, 4, 9, and 13 centimeters as is depicted in Table 5. Except for this difference, neither the cued nor the non-cued retrieval motor shadowing performances were differentially affected as a result of the number of lengths to be retrieved.

Table 5

Comparison of the Mean Absolute Error of the Angles in Motor Shadowing
When Performed Together With the Non-cued Retrieval of
9, 13, 9 and 13, 4, 9 and 13 Centimeter Lengths

Non-cued Retrieval Trials	Motor Shadowing and Retrieval 9 cm.	Motor Shadowing and Retrieval 13 cm.	Motor Shadowing and Retrieval 9 and 13 cm.	Motor Shadowing and Retrieval 4, 9 and 13 cm.
Mean Absolute Error of Angles in Degrees	51.38°	67.35	59.92	49.17
Motor Shadowing and Retrieval 9 cm.	-	2.66	1.42	0.37
Motor Shadowing and Retrieval 13 cm.		-	1.24	3.03*
Motor Shadowing and Retrieval 9 and 13 cm.			-	1.79
Motor Shadowing and Retrieval 4, 9 and 13 cm.				-

Required $S(3,87) = 2.71$ $p < .05$

* $p < .05$

CHAPTER V

DISCUSSION

Introduction

The principle objective of the present research was to determine whether the retrieval of kinesthetic sensory information from memory demands attention. Furthermore, it was possible to examine the relative attention demands of the information processing stages of encoding and response execution with respect to movement information. The research parallels efforts in the verbal domain to use the divided attention effect as a methodological tool for monitoring the memory processes. Within the dual task conditions instructions always emphasized that attention must be focused on the memory process tasks of encoding, retrieval or response execution with only any additional attention being devoted to the secondary motor shadowing task. In agreement with previous work (Johnston et al., 1970 and Trumbo and Milone, 1971) the divided attention effect was obtained. Secondary motor shadowing was sensitive to the attention demands of encoding, retrieval and execution of movement information. This was controlled by the implementation of the controls for primary task performances and therefore hypotheses five, six, seven and eight were accepted.

Three dependent measures, angles, percentage of direction changes and lengths of lines in motor shadowing were chosen to evaluate secondary motor shadowing performances. However, while values of the mean absolute error of angles and the percent of missed direction changes exhibited comparable indices of the demands of encoding, retrieval and movement execution, the values of the mean absolute error of the lengths of movement shadowed was insensitive to the primary task demands.

The first section of the discussion will be devoted to an explanation of the variation in performance in direction and distance reproduction when shadowing a kinesthetic sensory input. Based on the following interpretation, the remainder of the discussion will be focused on the measurement of secondary motor shadowing performance with respect to direction of movement. The second section will examine the principle aspect of the study--the attention demands of retrieval from memory. The remaining two sections will consider the attention demands of encoding and response execution processes.

Distance and Direction Information

Prior to discussing the memory processes investigated, it was necessary to examine the findings with respect to the dependent variables, angles, the percent of direction changes and lengths of movements in motor shadowing. An explanation for the divergence of reproduction of direction

and distance is the levels of processing interpretation of Craik and Lockhart (1972) and Juola, Taylor, and Young (1974). The basic differences in direction and distance may be attributed to the nature of encoding each of these forms of movement information. Firstly, in accordance with the proposal of Hall and Leavitt (1977) it may be that distance information is encoded at the perceptual level while direction may be encoded at a conceptual level. Hence, the perceptual encoding of the distance attribute allowed reproduction but with little accuracy. In fact, when secondary motor shadowing was performed alone, the mean absolute error in the lengths of movement was 4.9 centimeters--approximately half the distance the subjects were supposed to move. In comparison, the mean absolute error of angles in motor shadowing alone was 22.67 degrees while no direction changes were missed. Thus, encoding of the directional attribute of the movement was probably at a conceptual level.

An interesting aspect of the study was that while the distance information in motor shadowing was not reproduced accurately, subjects were able to successfully reproduce the three movement lengths learned either separately or in combination. The obvious inaccuracy in reproduction of distance information in motor shadowing as compared to the accurate reproduction of the movement lengths in retrieval may be explained by the model of

Juola et al. (1974). In retrieval, the distances were extensively rehearsed and like Chabot, Miller, and Juola (1976) for words and pictures, the distance information in this instance may have led to the formation of a stronger memory trace at the perceptual level of processing. However, in motor shadowing the patterns presented were novel and, hence, would be coded at a shallow depth of processing determined by the physical attributes of the distance information alone.

Another possibility for superior performance in retrieval of distances as opposed to encoding the distances in motor shadowing could be that through rehearsal in the retrieval conditions, the distance information may have been transformed from a perceptual to a conceptual level of processing--semantics being associated with the three movement lengths (Lockhart et al., 1975). This latter explanation is considered the most appropriate. When questioned after the experiment, subjects divulged that they had identified the three lengths as short, medium and long which would support the notion of conceptual encoding whereby an event is mapped into a class of events that differentiate it from other events of the same class.

Although subjects identified the lengths as short, medium and long, almost without exception all three movement lengths were overestimated with four centimeters, for instance, being generally considered

in the vicinity of four inches. This observation is most interesting when it has been proposed that some kinesthetic information when coded may eventually be transformed into a conceptual, visual and kinesthetic code (Diewert, 1975). Obviously the visual and kinesthetic codes were not compatible and yet the subjects were able to reproduce the designated distances. The understanding of the coding of movement information, particularly distance, awaits the findings of future research.

Memory Processes

The results of this study were incongruous with the proposals by Posner and Boies (1971) that encoding does not require attention, and Keele (1972, 1973) that retrieval of information from memory was an automatic non-attentive process. The results provided strong evidence that each of the stages in information processing demanded attention and, hence, access to central processing capacity. The error measures of direction in motor shadowing exhibited the predicted differential effects of the memory processes. The relative magnitude of interference to motor shadowing of each memory process was in agreement with previous verbal studies which have specifically isolated the memory processes using a continuous secondary task of tracking (Trumbo and Noble, 1970; Johnston et al., 1972; Trumbo and Milone, 1972). In each of these studies, memory retrieval

of verbal material was shown to be reflected in tracking as the most attention-demanding stage of processing followed by encoding and then overt response. In the present study, retrieval from memory was the most attention demanding.

The mean absolute error of angles in degrees for non-cued, cued retrieval, encoding response execution, and motor shadowing were 58.80, 47.32, 38.87, 35.50 and 22.67 respectively. The finding that non-cued retrieval and cued retrieval demanded more attention than encoding and response execution allows hypotheses one, two, three and four to be accepted.

Memory Retrieval

The retrieval of information from memory is viewed as containing two distinct operations (Sternberg, 1969, 1975; Anderson and Bower, 1972, 1974; Reed, 1976; Wicklegren and Corbett, 1977). Information is recovered from memory through a search process and this is followed by a decision to either terminate the search and respond if the appropriate information is retrieved, or, alternatively, continue the search.

In an attempt to examine the retrieval process in some depth, two retrieval conditions of different magnitude were introduced. Firstly, in cued retrieval where the length(s) to be retrieved were known prior to the reproduction, it was assumed the subject was able to recover

the appropriate representation in advance and, hence, eliminate the search process. However, in the non-cued retrieval condition where the lengths were not known until the actual movement was commenced, the assumption was that the subject had to search and recover the appropriate representation as well as make the decision when to terminate the movement. Hypothesis nine is accepted the results indicating that pre-cuing of the information to be retrieved has a facilitatory effect on the subsequent retrieval performance as evidenced by the greater decrement (11.48 degrees greater for angles and 7.13% for directional changes missed) in the non-cued retrieval condition.

By implementing the two forms of retrieval, it was possible to equate the retrieval process with paradigms which have evaluated memory processes contrasting recognition to recall retrieval (Anderson and Bower, 1972; Tulving and Thompson, 1973). In recall, the search is considered relatively extensive to retrieve the appropriate information while in recognition retrieval the item is presented. Hence, in recognition the search is only necessary to the extent that it confirms the decision chosen with respect to the information presented. While it was assumed that both cued and non-cued retrieval were recall performances, by providing subjects with the information prior to the actual performance, it is quite conceivable that the search process had been...

eliminated. Hence, all that was required was the decision to terminate the movement when it was considered the designated length was reproduced and, therefore, this condition was actually a measure of recognition retrieval. Such an interpretation would provide a plausible explanation of the greater accuracy in cued retrieval performance.

Sternberg (1969, 1975), from reaction time experiments examining the retrieval of verbal information, has presented data which would indicate that the latency of the response is a linear function of the size of the set from which the response must be made. Accordingly, the number of movement lengths to be retrieved was manipulated to determine whether the accuracy of motor shadowing was a function of the number of learned movements retrieved. The error of the angles in motor shadowing was significantly greater for one length of 13 centimeters (67.35 degrees) than for three movement lengths of 4, 9, and 13 centimeters together (49.17 degrees), which is the opposite effect with one movement item demanding more attention for retrieval than three movement items. However, subjects were given practice combining the lengths in the learning phase and it is possible the lengths may have been combined and conceptually coded into one additional movement length. However, this finding is of particular interest as the longer movement (26 centimeters) when the three learned lengths were combined.

required less attention than the shorter lengths of 9 and 13 centimeters when retrieved separately. Research of the past five years (Martenuik and Roy, 1972; Martenuik, 1973; Laabs, 1973; Roy, 1976) has indicated that the longer the distance the less accurate the reproduction which would tend to suggest that the longer movement would require more attention. However, it appears the shorter movement demanded more attention as evidenced by the greater decrement in motor shadowing performance.

A further point to note in retrieval is that should the movement reproduction in retrieval be based on kinesthetic feedback, then the limitation in processing may be that this feedback processing is overlapping with the processing of the kinesthetic feedback from the presentation of the movement in motor shadowing. If movement execution in retrieval is based on a motor program which has been developed through rehearsal of the lengths, then there would be no overlap and the interference in motor shadowing would be solely due to the processing requirements of retrieving the motor program. The present study is unable to distinguish between these two possibilities although the method employing motor shadowing would indicate that this question may be answered with further research of the same basic experimental paradigm.

Encoding

It is apparent that the encoding of movement information is an attention-demanding process as evidenced by the significant decrement in motor shadowing performance when combined with this process. The increase in the mean absolute error of angles, in degrees, was 16.20 while there was a 15.27% increase in the number of directional changes missed.

This finding concurs with Johnston et al. (1972), Trumbo and Noble (1972) from studies employing tracking as the secondary task, and Comstock (1973) and Miller (1975) both using a probe secondary task. To explain why the encoding of movement information requires attention and thus access to central processing capacity, again the levels of processing models of either Juola et al. (1974) or Lockhart et al. (1975) may be appropriate. The subject knew the two lengths to be compared would be from the three lengths learned. Thus, it would be inevitable that the spread of processing of this information at the perceptual level would have strengthened the memory trace for recognition (Juola et al., 1974) or alternatively he would assign a category (short, long or medium) to the lengths presented and accordingly the lengths would be encoded at the conceptual level (Lockhart et al., 1975) synonymous to the encoding during movement reproduction in retrieval. Based on the finding of the present study,

that encoding of movement information requires attention, it would appear the encoding operation is a crucial variable to the success of subsequent retrieval of the stored representation of the encoded item as emphasized by Tulving's Encoding Specificity Principle.

Response Execution.

The response execution condition was included as a control to determine the attention demands of the overt response during the retrieval of movement lengths. It was assumed that such a movement would require minimal attention as it was guided by two metal runners and its termination was controlled by the experimenter using a wooden stopper. Having to execute the movement while shadowing caused the error in motor shadowing to increase 12.83 degrees above the error while shadowing alone. The percentage of direction changes missed increased from zero to 11.63% when motor shadowing was combined with response execution. Actually, the attention demands were equatable with the condition involving encoding--the difference in the mean absolute error of the angles in degrees between encoding and response execution was only 3.37. Similarly, the difference in the percentage of direction changes missed was only 3.64%. The attention was attributed primarily to the initiation of the movement.

Although the motor shadowing measure was not sensitive enough to determine precisely where the attention demands were during the course of the movement from observation, it appeared the greatest interference occurred primarily in the initial phase. This interpretation, based on experimental observation, does concur with previous findings of Posner and Keele (1969) and Ellis (1969, 1973), both of whom reported the longest latency of reaction time to a secondary probe in movement execution being at initiation of the movement.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

Man is viewed as a limited processor of information and selective attention is the phenomena whereby information from one source is processed while other sources of information are ignored. Investigations of the past decade have concentrated on where selection occurs. Studies have dealt with the reception of sensory input information throughout processing to the final output in response. The three principle stages in processing which have been delineated are encoding, retrieval of information from memory and overt response execution. One explanation forwarded to explain why it is possible in one situation to process two inputs simultaneously while in another to process in a serial manner, is that certain processing stages do not require attention. In fact, it has been proposed on different occasions that each of the processing stages of encoding, retrieval and response execution may not require attention.

This study was primarily designed to determine the attention demands of the retrieval of kinesthetic sensory information from memory. To investigate this memory

process it was necessary to distinguish attention demands of the retrieval process, the encoding process and those of the overt response (motor output). Accordingly, the attention demands of the three processes were determined separately in processing kinesthetic sensory information. The study was confined to the kinesthetic sensory system to establish whether kinesthetic processing actually differs from the more traditional visual and auditory processing, either in its limitations or its basic method of operation.

A total of thirty first year male and female students from Introductory Psychology participated in two one-hour sessions. The apparatus consisted of two pantographs which were in a one-to-one correspondence with two handles controlled by two experimenters. On the first day, subjects learned three movement lengths--4, 9, and 13 centimeters--which were presented to the left hand through the kinesthetic sensory system with visual and auditory cues excluded. The movement of the left pantograph was guided and all movements were made in a straight forward motion. Once the subject could reproduce the distances on five consecutive reproductions, ($\pm 10\%$), it was assumed that the lengths had been encoded into memory. Retention of the lengths was measured after five minutes and again the following day after 24-hours.

On the second day, after any necessary relearning of the lengths, the experimental phase was conducted. In the experimental phase the attention demands of each of the processing stages was assessed. Two forms of retrieval--cued retrieval and non-cued retrieval--were included. In cued retrieval the lengths to be reproduced were known before the recall trial commenced. In non-cued retrieval the lengths were not known until after the commencement of the retrieval performance. Subjects were required to retrieve the lengths by pushing the left pantograph forward. In encoding, subjects compared two of the learned movement lengths and were required to determine whether the two lengths presented were the 'same' or 'different'. In response execution, the subject performed a 21-centimeter movement by pushing the left pantograph forward until the movement was stopped by the experimenter.

The attention demands of each of these tasks was determined by its interference with a secondary shadowing task. In secondary task of motor shadowing, the subjects replicated movement presented to the right hand with the right foot. A footpiece with a magic marker was secured to the foot and the movement was recorded as the foot moved across a sheet of paper. Two indices of motor shadowing performance were the mean absolute error of the lengths and angles when compared with those present-

ed to the hand. The third measure was the percent of missed direction changes.

It was found that there were no observed differences between the sexes in processing kinesthetic sensory information. However, contrary to postulates of several researchers, each of the memory processes demanded attention and, hence, required access to central processing capacity. Clearly the greatest attention demands were made during the retrieval of movement lengths not known prior to the beginning of retrieval performance. The attention demands of both encoding and response execution were statistically significant as reflected by increased errors during motor shadowing when combined with each of these tasks.

Conclusions

1. The error of motor shadowing when combined with each of the processing tasks was greatest for the retrieval of lengths from memory in both the cued and non-cued recall conditions, which indicates that the retrieval of the movement lengths demanded attention.
2. The retrieval of movement lengths from memory was facilitated by prior knowledge of the movement information to be retrieved.
3. Based on the finding that stimulus encoding, retrieval and response execution processes caused a significant

decrement in motor shadowing of kinesthetic sensory information, it appears that all stages of information processing require attention.

Hence a model that depicts any processing stages as being nonattentive is inappropriate as an explanation of successful human processing of two simultaneous inputs.

Recommendations

1. As all processing stages demanded attention it appears that the question of where selection occurs is inappropriate and more effort should be directed toward quantifying the relative demands of each stage depending on the nature of the activity. When attempting to speak of any process with respect to its demands on central processing capacity, it is imperative that the level of encoding, retrieval extent and the complexity of the response involved be included as essential variables.
2. By providing the subject with the information to be retrieved prior to the retrieval performance it is conceivable the memory search process is eliminated. Hence, what is considered recall retrieval may actually be recognition retrieval. The only real memory requirement in cued retrieval may be the decision to terminate the movement. This interpretation may assist in understanding and distinguishing between the two forms of retrieval and

help explain the different findings that may be a result of using recognition or recall paradigms.

3. While the visual system is considered the dominant sense, the kinesthetic system and the production of movement is the principle nonverbal means by which man expresses himself. However, the present knowledge of the attributes of movement--distance, direction, velocity, torque and time, is limited. The understanding of the coding of movement attributes into internal representations for storage in memory and subsequent retrieval is an area upon which to focus future research efforts.
4. The technique of motor shadowing appears to be a sensitive measure of the attention demands requiring continuous information processing throughout the presentation of a kinesthetic sensory input. The technique should be employed further in the study of the nature and functions of the human information processor particularly in the realms of motor learning and human performance.

Practical Application

1. The attention demands of the retrieval of movement information indicates that it may be a major contributor to the disruption in acquisition and retention of motor skills. Accordingly, educators should always endeavour to provide as much assistance as possible to facilitate

the retrieval process.

2. The coding of distance information seems to be very inaccurate but may be transformed to an accurate memory trace with rehearsal. However, the number of trials following each retention interval necessary to attain the pre-established criterion performance of each of the three movement lengths would suggest that considerable rehearsal of distance information is necessary before this attribute is stored relatively permanently. Educators should realize the inability to code and retain the distance information through kinesthesia only and, hence, use other movement attributes when developing motor skills.

APPENDIX A
INSTRUCTIONS TO SUBJECTS

The following prerecorded instructions were read to subjects prior to each experimental condition.

Condition 1 - Encoding

In this condition the commencement of the masking noise on the earphones will indicate to place both hands on the handles. I will then present a movement length to your left hand. At the completion of the presentation of this movement length the left hand should be lifted from the handle and then replaced when the masking noise is turned off and on. I will then present a second movement length. At the completion of this movement length both hands should be replaced on the lap. Then you should give a verbal response, same or different, based on the comparison of the two lengths presented. Remember, I will make the movement for you. All I want you to do is to compare the two lengths presented and give the response, "the same" or "different". Are there any questions?

Condition 2 - Cued Retrieval

In this condition I will indicate the number of a length which you have previously learned, 1, 2 or 3, which I want you to reproduce by moving the left hand forward. When you consider you have reproduced the distance corresponding to the number the hands should then be replaced on the lap. On any trial, if more than one number is indicated, for example, 1 and 2, or 2 and 3, or even 1, 2 and 3, you are to reproduce the total distance

corresponding to the numbers in one continuous movement. Once you have reproduced the distance the hands should be replaced on the lap. The next trial will be commenced by the indication of the number or numbers corresponding to the distance you are required to reproduce. Are there any questions?

Condition 3 - Non-cued Retrieval

In this condition as soon as you hear the masking noise on the earphones place both hands on the handles. You will then commence movement of the left hand slowly forward. As soon as you do this I will indicate to you the number of a length which you have previously learned 1, 2 or 3 which I want you to reproduce. When you consider you have reproduced the distance corresponding to the number the hands should then be replaced on the lap. The distance moved prior to the number being given should be included as part of the total distance moved. On any trial if more than one number is indicated, for example, 1 and 2, or 2 and 3, or even 1, 2 and 3, you are to reproduce the total distance corresponding to the numbers in one continuous movement. Once you have reproduced the distance the hands should be replaced on the lap. Then the masking noise will be turned off and one to indicate to place both hands on the handles and commence the movement for the next trial. Remember in this condition you will commence movement of the left hand slowly. I will

then indicate the number or numbers corresponding to the length of movement which I want you to reproduce. Are there any questions?

Condition 4 - Response Execution

In this condition when you hear the commencement of the masking noise on the earphones both hands should be placed on the handles. The left hand should then be moved slowly and smoothly forward until the movement is stopped. I want you to remember to make the movement with the left hand in a slow, smooth, continuous motion. I will stop the movement. You continue to push the handle forward until the movement is stopped. Then replace both hands on the lap. The masking noise will be turned off and on to indicate the commencement of the next trial. Are there any questions?

Condition 5 - Motor Shadowing

In this condition you will be required to shadow movement presented to your right hand with your right foot as you did in the practice session yesterday. I want you to remember to move your foot in the same direction, the same distance and change direction, at the same angle with your foot as is being presented to your hand. At the completion of the movement to your right hand keep your foot still and replace your hands on your lap. However, don't be alarmed if I then move your foot to assist me in rolling the paper along for the next trial. The start of the

first trial will be indicated by the commencement of the masking noise on the earphones. Further trials will be commenced by the masking noise being turned off and on. At this time the hands should be replaced on the handles ready for the commencement of the next trial. Are there any questions?

Condition 6 - Encoding and Motor Shadowing

In this condition the commencement of the masking noise on the earphones will indicate to place both hands on the handles. I will then present a movement length to your left hand. On the completion of this movement the hand should be removed from the handle. The masking noise will be turned off and on to signify to replace the handle. I will then present a second movement length. After this the hands should be replaced on the lap and the response same or different based on the comparison of the two lengths presented should be given by you. At the same time as I commence the movement of the second length, Cathy will present movement to the right hand. You may shadow this movement by moving the right foot as you have done previously. Remember to move the foot in the same direction, the same distance and change directions at the same angle as is being presented to the right hand. As soon as I have completed presenting the second movement length Cathy will stop presenting movement to the right hand. Therefore, as soon as this occurs you should keep

the foot still. In this condition it is most important that you give a correct response same or different based on the comparison of the two lengths presented to the left hand. Therefore, you should only give as much attention to shadowing the movement presented to the right hand as this task permits. If on any trial you give an incorrect response whether it be same or different, a further trial must be given. The commencement of trials in this condition will be indicated by the masking noise being turned off and on. The hands should then be placed on the handles ready for the presentation of the first movement length. Are there any questions?

Condition 7 - Cued Retrieval and Motor Shadowing

In this condition prior to the commencement of the masking noise on the earphones I will indicate the number corresponding to the length I want you to reproduce by moving the left hand forward. If more than one number is given then the total distance corresponding to the numbers should be reproduced in one continuous motion. When you consider you have reproduced the designated distance the hands should be replaced on the lap. At the same time as you commence reproducing the distance indicated, Cathy will present movement to the right hand. You may shadow this movement with the right foot. Remember to move the foot in the same direction, the same distance and change directions at the same angles with the foot as is being

presented to the right hand. At the completion of reproducing the movement with the left hand movement to the right hand will cease. You then stop shadowing, keep the foot still and wait for the next trial. In this condition it is most important you reproduce the distance indicated as accurately as possible. Therefore, you should only give as much attention to shadowing the movement presented to the right hand as reproducing the movement accurately allows you. If on any trial you do not reproduce the distance within a certain criterion previously established then a further trial will have to be given. Therefore, only give as much attention to shadowing as the task of reproducing the distance with the left hand allows you. The commencement of each trial in this condition will be preceded by the number or numbers of the movement being given on the earphones. Are there any questions.

Condition 8 - Motor Shadowing and Non-cued Retrieval

In this condition the commencement of the masking noise will indicate to place both hands on the handles. Then you should commence movement of the left hand forward. As soon as you do this I will give the number or numbers corresponding to the length of movement I want you to reproduce. If more than one number is given then the distance should be reproduced in one continuous motion. When you consider you have reproduced the distance indicated

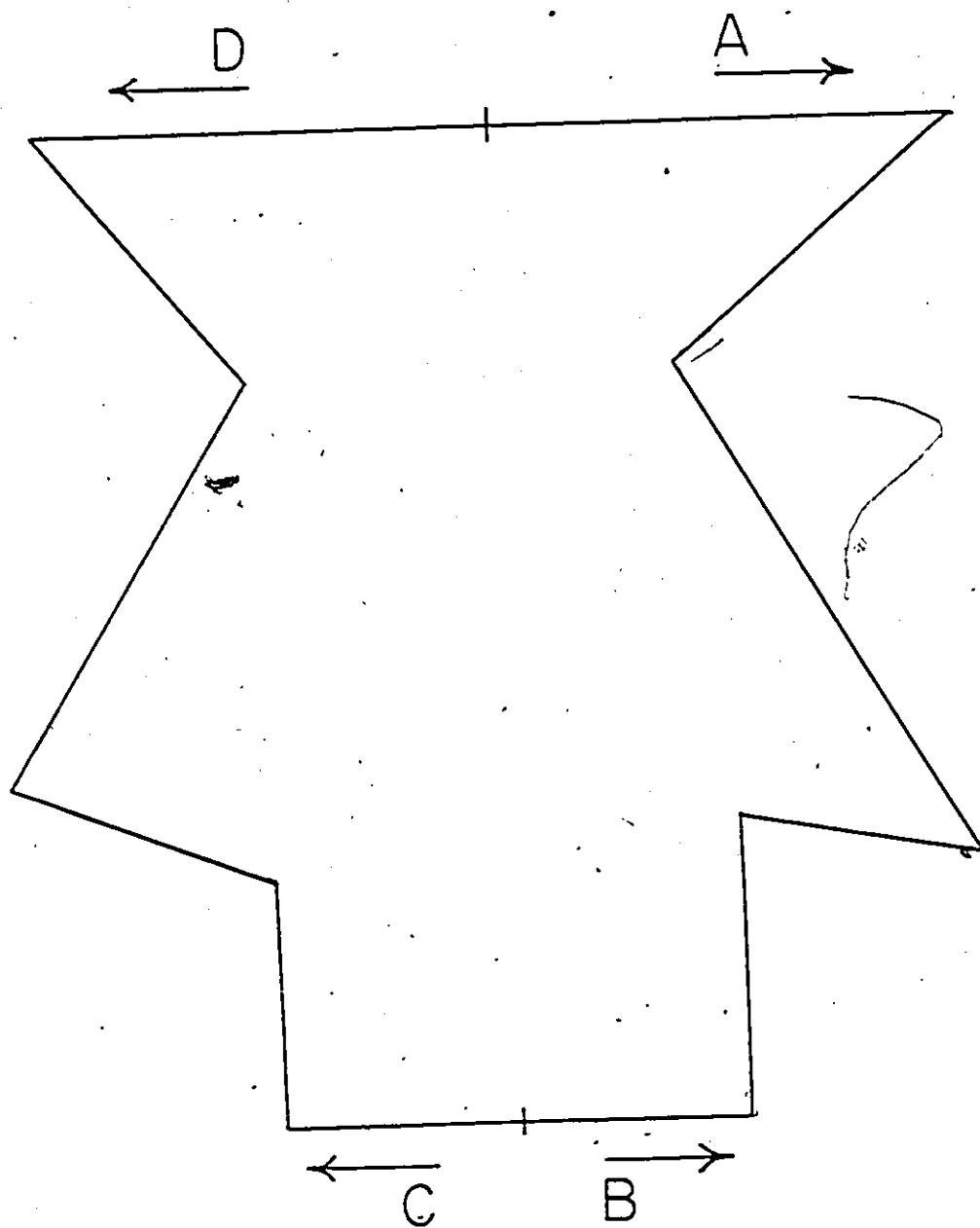
the hands should be replaced on the lap. At the same time as you commence movement of the left hand Cathy will present movement to the right hand. You may shadow this movement with the right foot. Remember to move in the same direction, the same distance and change direction at the same angle with the foot as is being presented to the right hand. It is most important in this condition you reproduce with the left hand the distance indicated. Therefore, you should only give as much attention to shadowing the movement presented to the right hand as this task allows. If on any trial you do not reproduce the distance within a certain criteria established, then a further trial must be given. The commencement of trials in this condition will be signalled by the masking noise being turned off and on. Are there any questions?

Condition 9 - Motor Shadowing and Response Execution

The commencement of trials in this condition will be signalled by the masking noise being turned on. You then place both hands on the handles and move the left hand slowly and smoothly forward until the movement is stopped. The hands should then be removed from the handles. At the same time as you commence movement of the left hand, Cathy will present movement to the right hand. You may shadow this movement with the right foot. Remember to move in the same direction, the same distance and change direction at the same angle with the foot as is being presented the

right hand. As soon as the movement of the left hand is stopped movement to the right hand will cease. In this condition it is most important that it is moved in a slow, smooth, continuous motion. You should only give as much attention to shadowing the movement presented to the right hand as moving in a slow, smooth, continuous motion. The speed should be at the same speed as when you made the movement alone previously. On any trial if you do not make the movement in a similar manner a further trial will have to be given. Are there any questions?

APPENDIX B
PATTERNS FOR MOTOR SHADOWING



SCALE:

0.5 cm = 1.0 cm

Figure 8 Patterns A, B, C and D which were used as kinesthetic sensory inputs in secondary motor shadowing performances.

APPENDIX C
ANALYSIS OF VARIANCE SUMMARY TABLES

Table 6
 Summary Table for the Analysis of Variance of Males and Females
 for the Mean Absolute Error of Angles in Motor Shadowing
 when Performed Alone and with Response Execution,

Encoding, Cued and Non-cued Retrieval

Source	SS	df	MS	F
Between Subjects	15384.06	29		
'A' Main Effects	318.69	1	318.69	0.59
Subjects Within Groups	15065.13	28	538.04	
Within Subjects	39011.75	120		
'B' Main Effects	21826.99	4	5456.75	36.64*
'AB' Interaction	506.25	4	126.56	0.85
'B' x Subjects Within Groups	16678.56	112	148.92	

*p < .05

Table 7

Summary Table for the Analysis of Variance of Males and Females
for Number of Direction Changes Missed in Motor Shadowing
when Performed Alone and with Response Execution,
Encoding, Cued and Non-cued Retrieval

Source	SS	df	MS	F
Between Subjects	2.27	29		
'A' Main Effects	0.05	1	0.05	0.65
Subjects Within Groups	2.21	28	0.08	
Within Subjects	6.26	120		
'B' Main Effects	3.39	4	0.85	
'AB' Interaction	0.05	4	0.01	
'B' x Subjects Within Groups	2.82	112	0.03	

*p < .05

Table 8

Summary Table for the Analysis of Variance of Males and Females
for the Mean Absolute Error of the Lengths in Motor Shadow-
ing when Performed Alone and with Response Execution,
Encoding, Cued and Non-cued Retrieval

Source	SS	df	MS	F
Between Subjects	494.40	29		
'A' Main Effects	0.30	1	0.30	0.02
Subjects Within Groups	494.10	28	17.65	
Within Subjects	308.32	120		
'B' Main Effects	25.70	4	6.43	2.58*
'AB' Interaction	3.72	4	0.93	0.37
'B' x Subjects Within Groups	278.90	112	2.49	

*p < .05

Table 9

Summary Table for the Analysis of Variance for the Mean Absolute Error of Angles in Motor Shadowing when Performed Alone and with Response Execution, Encoding, Cued and Non-cued

Retrieval				
Source	SS	df	MS	F
Between Subjects	15425.62	29	531.92	
Within Subjects	38999.81	120	325.00	
Treatments	21814.06	4	5453.52	36.81*
Residual	17185.75	116	148.15	
Total	54425.43	149		

*p < .05

Table 10

Summary Table for the Analysis of Variance for the Number of
Direction Changes Missed in Motor Shadowing when Performed
Alone and with Response Execution, Encoding, Cued and

Non-cued Retrieval

Source	SS	df	MS	F
Between Subjects	2.19	29	0.08	
Within Subjects	5.90	120	† 0.05	
Treatments	3.17	4	0.79	33.80*
Residual	2.72	116	0.02	
Total	8.09	149		

*p < .05

Table 11
 Summary Table for the Analysis of Variance of the Absolute Error
 of Lengths in Motor Shadowing when Performed Alone and
 with Response Execution, Encoding, Cued and
 Non-cued Retrieval

Source	SS	df	MS	F
Between Subjects	494.41	29	17.05	
Within Subjects	308.24	120	2.57	
Treatments	25.71	4	6.43	2.64
Residual	282.53	116	2.44	
Total	802.65	149		

*p < .05

Table 12

Summary Table for the Analysis of Variance of the Mean Absolute Error
of the Angles of Motor Shadowing for Cued Retrieval of
9, 13, 9 and 13, 4, 9, and 13 Centimeter Lengths

Source	SS	df	MS	F
Between Subjects	21534.00	29	797.55	
Within Subjects	49876.00	90	593.76	
Treatments	1464.63	3	488.21	0.82
Residual	48411.37	87	597.67	
Total	71410.00	119		

Table 13

Summary Table for the Analysis of Variance for the Mean Absolute Error
of the Lengths of Motor Shadowing for Cued Retrieval of
9, 13, 9 and 13, 4, 9, and 13 Centimeter Lengths

Source	SS	df	MS	F
Between Subjects	390.11	29	13.45	
Within Subjects	674.45	90	7.49	
Treatments	29.86	3	9.95	1.34
Residual	644.60	87	7.41	
Total	1064.57	119		

Table 14

Summary Table for the Analysis of Variance of the Mean Absolute Error
of the Angles of Motor Shadowing for Non-cued Retrieval of
9, 13, 9 and 13, 4, 9, and 13 Centimeter Lengths

Source	SS	df	MS	F
Between Subjects	30442.00	29	1049.72	
Within Subjects	53322.12	90	592.47	
Treatments	6257.69	3	2085.90	3.86*
Residual	47064.43	87	540.97	
Total	83764.12	119		

*p < .05

Table 15

Summary Table for the Analysis of Variance of the Mean Absolute Error
of the Lengths of Motor Shadowing for Non-cued Retrieval
of 9, 13, 9 and 13, 4, 9, and 13 Centimeter Lengths

Source	SS	df	MS	F
Between Subjects	385.38	29	13.29	
Within Subjects	464.16	90	5.16	
Treatments	19.11	3	6.37	1.25
Residual	445.04	87	5.12	
Total	849.53	119		

APPENDIX D

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS

Presentation Order of Experimental Conditions

Conditions:

1. Encoding
2. Cued Retrieval
3. Non-cued Retrieval
4. Response Execution
5. Motor Shadowing Alone
6. Motor Shadowing and Encoding
7. Motor Shadowing and Cued Retrieval
8. Motor Shadowing and Non-cued Retrieval
9. Motor Shadowing and Response Execution

FEMALES

Subject Number	Order of Presentation									
	Single Tasks					Dual Tasks				
1	3	4	1	2		6	7	8	9	5
2	4	1	2	3		7	8	9	5	6
3	4	1	2	3		6	7	8	9	5
4	1	2	3	4		5	6	7	8	9
5	2	3	4	1		7	8	9	5	6
6	2	3	4	1		9	5	6	7	8
7	1	2	3	4		7	8	9	5	6
8	3	4	1	2		8	9	5	6	7
9	4	1	2	3		9	5	6	7	8
10	4	1	2	3		5	6	7	8	9
11	2	3	4	1		8	9	5	6	7
12	1	2	3	4		6	7	8	9	5
13	1	2	3	4		8	9	5	6	7
14	3	4	1	2		9	5	6	7	8
15	3	4	1	2		5	6	7	8	9

MALES

Order of Presentation

Subject Number	Single Tasks				Dual Tasks				
1	4	1	2	3	9	5	6	7	8
2	1	2	3	4	5	6	7	8	9
3	2	3	4	1	9	5	6	7	8
4	3	4	1	2	8	9	5	6	7
5	3	4	1	2	5	6	7	8	9
6	4	1	2	3	7	8	9	5	6
7	2	3	4	1	8	9	5	6	7
8	1	2	3	4	8	9	5	6	7
9	2	3	4	1	7	8	9	5	6
10	1	2	3	4	6	7	8	9	5
11	4	1	2	3	5	6	7	8	9
12	1	2	3	4	7	8	9	5	6
13	3	4	1	2	6	7	8	9	5
14	4	1	2	3	6	7	8	9	5
15	3	4	1	2	9	5	6	7	8

APPENDIX E
MOVEMENT LENGTHS AND PATTERNS PRESENTED ON THE FOUR
TRIALS OF THE EXPERIMENTAL CONDITIONS

Table 16

Movement Lengths and Patterns Presented on the Four

Trials of the Experimental Conditions

		Trial 1	Trial 2	Trial 3	Trial 4
Condition 1	Encoding	9/9	9/13	4/9	13/13
Condition 2	Cued Retrieval	9	13	4, 9, 13	9, 13
Condition 3	Non-cued Retrieval	9, 13	9	4, 9, 13	13
Condition 4	Response Execution	21	21	21	21
Condition 5	Motor Shadowing Alone	A	D	B	C
Condition 6	Motor Shadowing and Encoding	B	C	A	D
Condition 7	Motor Shadowing and Cued Retrieval	D	A	C	B
Condition 8	Motor Shadowing and Non-cued Retrieval	C	B	A	D
Condition 9	Motor Shadowing and Response Execution	A	D	C	B
		21	21	21	21
					128.

APPENDIX F
EXPERIMENTAL DATA

RESPONSE EXECUTION TIMES FOR THREE SEVEN CENTIMETER SEGMENTS IN THE SINGLE
AND DUAL TASK CONDITIONS

FORMAT (6F5.4)		
COLUMNS 1-5	SEGMENT 1	
COLUMNS 6-10	SEGMENT 2	
COLUMNS 11-15	SEGMENT 3	
COLUMNS 16-20	SEGMENT 1	
COLUMNS 21-25	SEGMENT 2	
COLUMNS 26-30	SEGMENT 3	
COLUMNS 69-70	DATA DECK NUMBER	
COLUMNS 72-73	SUBJECT NUMBER	
COLUMNS 75-80	SEX	
192633094132084116081651631258		
150591043016077088620606112266		
089480869415427109030712715245		
309144225140274284382651544726		
154221485511562165461291613375		
149841918411790105571442308315		
137891764816732090231141412024		
150661921614270119171837315316		
261854295935549189532960732118		
172052080916570151552279821356		
159572138217924177682698825462		
43103602175185436955534648482		
315663422940928277565200938839		
153702111919514150062065124805		
23674326012785229692903137428		
137131975805535113811245612162		
200392297816560164912667015578		
100651015512047105450902714479		
095251428210172087861282213694		
112611879321746100802285821305		
177543393110702154722591119463		
225743263639554195852522335200		
249132563924406223773299721175		
233763181036585292063502139804		
170642204125107223102823530132		
145091965421229125202065723656		
255713991543300213832883727468		
176433432035080264323254926319		
198051360123223246371792412453		
2603052666042984286274683643592		

06	01	MALE
06	02	MALE
06	03	MALE
06	04	MALE
06	05	MALE
06	06	MALE
06	07	MALE
06	08	MALE
06	09	MALE
06	10	MALE
06	11	MALE
06	12	MALE
06	13	MALE
06	14	MALE
06	15	MALE
06	01	FEMALE
06	02	FEMALE
06	03	FEMALE
06	04	FEMALE
06	05	FEMALE
06	06	FEMALE
06	07	FEMALE
06	08	FEMALE
06	09	FEMALE
06	10	FEMALE
06	11	FEMALE
06	12	FEMALE
06	13	FEMALE
06	14	FEMALE
06	15	FEMALE

MEAN ABSOLUTE ERROR OF ANGLES IN DEGREES DRAWN BY SUBJECTS ON FOUR TRIALS IN
THE SINGLE AND DUAL TASK CONDITIONS. CONDITIONS 5, 6, 7, 8, AND 9

FORMAT (5F4.2)

COLUMNS 1-4 MOTOR SHADOWING AND ENCODING
COLUMNS 5-8 MOTOR SHADOWING AND CUED RETRIEVAL
COLUMNS 9-12 MOTOR SHADOWING AND NON-CUED RETRIEVAL
COLUMNS 13-16 MOTOR SHADOWING AND RESPONSE EXECUTION
COLUMNS 17-20 MOTOR SHADOWING AND RESPONSE EXECUTION
COLUMNS 69-70 DATA DECK NUMBER
COLUMNS 72-73 SUBJECT NUMBER
COLUMNS 75-80 SEX

13191933248731181418	01	01	MALE
28443092608865005072	01	02	MALE
22387780509368172383	01	03	MALE
229012933335860391948	01	04	MALE
18385263359838483392	01	05	MALE
36254062615887673617	01	06	MALE
22925539500865333725	01	07	MALE
24944225504484833408	01	08	MALE
37125633907561854931	01	09	MALE
21254458718357175333	01	10	MALE
18814288825074623167	01	11	MALE
16382925170042082694	01	12	MALE
22563038564459193448	01	13	MALE
2231415029444002769	01	14	MALE
22563362290530533033	01	15	MALE
22502592332556882058	01	01	FEMALE
278856193029442335819	01	02	FEMALE
36305073554079505013	01	03	FEMALE
14001675415074625153	01	04	FEMALE
22256883531772754789	01	05	FEMALE
27562292467545864325	01	06	FEMALE
15943183507540561917	01	07	FEMALE
19251350311265311902	01	08	FEMALE
17692850321234563088	01	09	FEMALE
24062914470857564648	01	10	FEMALE
21193664684486504108	01	11	FEMALE
24313080182729423942	01	12	FEMALE
17256938575872382575	01	13	FEMALE
19693422565628752983	01	14	FEMALE
19814042281258382435	01	15	FEMALE

PERCENTAGE OF DIRECTIONAL CHANGES MISSED IN MOTOR SHADOWING ON FOUR TRAILS
IN THE SINGLE AND DUAL TASK CONDITIONS. CONDITIONS 5, 6, 7, 8, AND 9

FORMAT (SF2.2)
COLUMNS 1-2 MOTOR SHADOWING AND ENCODING
COLUMNS 3-4 MOTOR SHADOWING AND CUED RETRIEVAL
COLUMNS 5-6 MOTOR SHADOWING AND NON-CUED RETRIEVAL
COLUMNS 7-8 MOTOR SHADOWING AND RESPONSE EXECUTION
COLUMNS 9-10 MOTOR SHADOWING AND RESPONSE EXECUTION
COLUMNS 69-70 DATA DECK NUMBER
COLUMNS 72-73 SUBJECT NUMBER
COLUMNS 75-80 SEX

0011305409	03	01	MALES
0010202727	03	02	MALE
0050676700	03	03	MALE
0000002800	03	04	MALE
0012718930	03	05	MALE
0010507100	03	06	MALE
0027434330	03	07	MALE
0025447100	03	08	MALE
0633884515	03	09	MALE
0033885010	03	10	MALE
0017406720	03	11	MALE
0000000807	03	12	MALE
0012200900	03	13	MALE
0617143325	03	14	MALE
0000001200	03	15	MALE
0010176009	03	01	FEMALE
0025003625	03	02	FEMALE
0000676718	03	03	FEMALE
0000625033	03	04	FEMALE
0544576245	03	05	FEMALE
0000201807	03	06	FEMALE
0020301500	03	07	FEMALE
0000005400	03	08	FEMALE
0000171700	03	09	FEMALE
0000202208	03	10	FEMALE
0012508311	03	11	FEMALE
0012001020	03	12	FEMALE
0057607300	03	13	FEMALE
0011180000	03	14	FEMALE
0010102700	03	15	FEMALE

MEAN ABSOLUTE ERROR OF LENGTHS IN CENTIMETERS DRAWN BY SUBJECTS ON FOUR TRIALS
IN THE SINGLE AND DUAL TASK CONDITIONS. CONDITIONS 5. 6. 7. 8. AND 9

FORMAT (5F5.3)
COLUMNS 1-5 MOTOR SHADOWING
COLUMNS 6-10 MOTOR SHADOWING AND ENCODING
COLUMNS 11-15 MOTOR SHADOWING AND CUED RETRIEVAL
COLUMNS 16-20 MOTOR SHADOWING AND NON-CUED RETRIEVAL
COLUMNS 21-25 MOTOR SHADOWING AND RESPONSE EXECUTION
COLUMNS 69-70 DATA DECK NUMBER
COLUMNS 72-73 SUBJECT NUMBER
COLUMNS 75-80 SEX

02553050566032280645503925	01	MALE
0508006906052750807407558	02	MALE
0319506901046020415703095	02	MALE
0259202065046770603102780	02	MALE
0515206167084480716609166	02	MALE
0542004124051850777305201	02	MALE
0551605813059340428407336	02	MALE
0783608039053710561604651	02	MALE
0941610762084480574208902	02	MALE
0340504103067280518404873	02	MALE
032860309058770510305945	02	MALE
0411503224028280372302731	02	MALE
0288902582041870513703976	02	MALE
0698910921059300762105542	02	MALE
0434705445033510552913791	02	MALE
0477203373031750299006096	02	FEMALE
0286903850048270540305052	02	FEMALE
0931111050087580855911981	02	FEMALE
0579505763061540735104236	02	FEMALE
0601407834076630640811938	02	FEMALE
0316702466032420410104641	02	FEMALE
0443804639056870380703988	02	FEMALE
0555805912049350958407861	02	FEMALE
0378804933031670338802444	02	FEMALE
0368502999031350305303058	02	FEMALE
0358308899068830735110183	02	FEMALE
0516501767037390361606073	02	FEMALE
0491704406062740682305298	02	FEMALE
0831105658079960912008995	02	FEMALE
0325202682030420259602414	02	FEMALE

DISTANCE AND TIMES IN SECONDS OF MOVEMENTS IN CUED RETRIEVAL IN THE SINGLE AND DUAL TASK CONDITIONS

FORMAT (6F2.1.5.3.3.1.5.3.3.1.5.3)
 COLUMNS 1-2 DISTANCE 9 CENTIMETERS ALONE
 COLUMNS 3-7 TIME 9 CENTIMETERS ALONE
 COLUMNS 8-10 DISTANCE 13 CENTIMETERS ALONE
 COLUMNS 11-15 TIME 13 CENTIMETERS ALONE
 COLUMNS 16-18 DISTANCE 9 & 13 CENTIMETERS ALONE
 COLUMNS 19-23 TIME 9 & 13 CENTIMETERS TOGETHER
 COLUMNS 24-25 DISTANCE 9 CENTIMETERS TOGETHER
 COLUMNS 26-30 TIME 9 CENTIMETERS TOGETHER
 COLUMNS 31-33 DISTANCE 13 CENTIMETERS TOGETHER
 COLUMNS 34-38 TIME 13 CENTIMETERS TOGETHER
 COLUMNS 39-41 DISTANCE 9 & 13 CENTIMETERS TOGETHER
 COLUMNS 42-46 TIME 9 & 13 CENTIMETERS TOGETHER
 COLUMNS 69-70 DATA DECK NUMBER
 COLUMNS 72-73 SUBJECT NUMBER
 COLUMNS 75-80 SEX

5502890137029392140469088030571420479020905030	04	01	MALE
9504190140054292240502298032351400495320306319	04	02	MALE
9001949138028332320748391024461420268520008526	04	03	MALE
9905867124079762241146598046211240819620112245	04	04	MALE
9001742141021902080699797027301360230920403340	04	05	MALE
9402997131029552250379093028401430309020005030	04	06	MALE
9302892142042962200443699023241300236520303860	04	07	MALE
8701435124024302000461199024201360401520004723	04	08	MALE
961031712209552051405694106261431226423515108	04	09	MALE
9402141130034452200635297036481410362220006100	04	10	MALE
9004060135048852080754598042281270489322207162	04	11	MALE
900770212110813227162969407710191175623412936	04	12	MALE
9704615139061482051011592083471340978523014133	04	13	MALE
9603082143044172191004597042881400503923909987	04	14	MALE
9804720133056162200788085032201370384622007880	04	15	MALE
8701131140010832030236390009761410131620102170	04	01	FEMALE
8404580128048452240512797040851400382621104498	04	02	FEMALE
9001765137030662010399698018961390312022004170	04	03	FEMALE
9402605129032262110571590027431390295819905385	04	04	FEMALE
9701409130029392100563091018821400167622904805	04	05	FEMALE
9302971129033702100542099040651280498524007106	04	06	FEMALE
8106508134068192241468998067641370741922015796	04	07	FEMALE
9203222121039252280800099027561410402322008370	04	08	FEMALE
9804651119065092101150585055951280795523105402	04	09	FEMALE
9103248137054792100879087049651410686620309820	04	10	FEMALE
940240113005414230059098204348140042352506883	04	11	FEMALE
8506361127070532040741599078641411081722010263	04	12	FEMALE
8804441142044922050610997094851301027320007831	04	13	FEMALE
9006659141118262020852098081451400804721513311	04	14	FEMALE
9208181126108572001794098062981421003222315132	04	15	FEMALE

DISTANCE AND TIMES IN SECONDS OF MOVEMENTS IN NON-CUED RETRIEVAL IN THE SINGLE AND DUAL TASK CONDITIONS

FORMAT (6F2.1.5.3.3.1.5.3.3.1.5.3)
 COLUMNS 1-2 DISTANCE 9 CENTIMETERS ALONE
 COLUMNS 3-7 TIME 9 CENTIMETERS ALONE
 COLUMNS 8-10 DISTANCE 13 CENTIMETERS ALONE
 COLUMNS 11-15 TIME 13 CENTIMETERS ALONE
 COLUMNS 16-18 DISTANCE 9 & 13 CENTIMETERS ALONE
 COLUMNS 19-23 TIME 9 & 13 CENTIMETERS TOGETHER
 COLUMNS 24-25 DISTANCE 9 CENTIMETERS TOGETHER
 COLUMNS 26-30 TIME 9 CENTIMETERS TOGETHER
 COLUMNS 31-33 DISTANCE 13 CENTIMETERS TOGETHER
 COLUMNS 34-38 TIME 13 CENTIMETERS TOGETHER
 COLUMNS 39-41 DISTANCE 9 & 13 CENTIMETERS TOGETHER
 COLUMNS 42-46 TIME 9 & 13 CENTIMETERS TOGETHER
 COLUMNS 69-70 DATA DECK NUMBER
 COLUMNS 72-73 SUBJECT NUMBER
 COLUMNS 75-80 SEX

9002612143042132210512984032251420419921605235	07 01	MALE
9904817142054932410603792036751380320920805987	07 02	MALE
8802159138018872140937895027511270263820108579	07 03	MALE
8602332136042042240831396020051320493223805884	07 04	MALE
940519912508008198112709804436128111222410117	07 05	MALE
9802975132016362150349898018061330156221603453	07 06	MALE
970196713003232300501090017631400217120903390	07 07	MALE
9902302141034992010518592032391410284824005043	07 08	MALE
980624513009070217150759804454138111520315447	07 09	MALE
960120127041512180794282048761190648022405908	07 10	MALE
9503871128044252020729090034391340427322106627	07 11	MALE
9906890131103892251564896079081281047922417000	07 12	MALE
8705274143083062051411099086121250793624017215	07 13	MALE
940367313804927220893898035761350401523306262	07 14	MALE
9304640133062342251061984033291420522523208610	07 15	MALE
9601271135018052080328388013051300203022401875	07 01	FEMALE
9303075131050812120903396029101330446520610065	07 02	FEMALE
9001955132021702010485194014721310197619804070	07 03	FEMALE
9503415129033072160541882021861200264920605465	07 04	FEMALE
9903186132037892300531997020871380242519805957	07 05	FEMALE
9003503141038992310678790048741250284322006136	07 06	FEMALE
9806098140069382201536294071311380888722014670	07 07	FEMALE
920311014203434202074559104340190327421606285	07 08	FEMALE
950422714207522211235397051841381043820212540	07 09	FEMALE
9803495120052462160905092043591300546823305193	07 10	FEMALE
9803349139046892240633184026961370472324006202	07 11	FEMALE
900502312807407234073959807819128093323911864	07 12	FEMALE
9908185143084582110830896086701190922922409675	07 13	FEMALE
8704915137078862401268298049631361216520914106	07 14	FEMALE
9507033134103572201683297063361380927823715459	07 15	FEMALE

MEAN TIME IN SECONDS OF FOUR TRIALS FOR CRITERION LENGTHS 4CMS, 9CMS & 13CMS
IN INITIAL LEARNING PHASE

FORMAT (3F6.4)
COLUMNS 1-6 TIME OF MOVEMENT FOR 4CMS
COLUMNS 7-12 TIME OF MOVEMENT FOR 9CMS
COLUMNS 13-18 TIME OF MOVEMENT FOR 13CMS
COLUMNS 69-70 DATA DECK NUMBER
COLUMNS 72-73 SUBJECT NUMBER
COLUMNS 75-80 SEX

017531028903047900	08 01	MALE
024237012450031346	08 02	MALE
021926020170020130	08 03	MALE
027367051232069417	08 04	MALE
009472024585024530	08 05	MALE
015505022425029828	08 06	MALE
020252026585041802	08 07	MALE
019380056957058175	08 08	MALE
051907062715112347	08 09	MALE
019625033142033200	08 10	MALE
021755023472032367	08 11	MALE
039640086285096822	08 12	MALE
012535033952056412	08 13	MALE
021212033032034170	08 14	MALE
024670030322086840	08 15	MALE
011285014483016690	08 01	FEMALE
014773048223059360	08 02	FEMALE
006372004867006582	08 03	FEMALE
009897018000026620	08 04	FEMALE
018975018610021295	08 05	FEMALE
020885026225030512	08 06	FEMALE
046470059927076747	08 07	FEMALE
014837029612046197	08 08	FEMALE
048280063450072457	08 09	FEMALE
020180032245043532	08 10	FEMALE
011225021265023827	08 11	FEMALE
021682052435060697	08 12	FEMALE
018747028207040702	08 13	FEMALE
037172073077050022	08 14	FEMALE
020305040567035247	08 15	FEMALE

NUMBER OF LEARNING TRIALS FOR CRITERION LENGTHS DURING INITIAL LEARNING
5 MINUTES RETENTION & 24 HOUR RETENTION

FORMAT (9F2.0)	COLUMNS 1-2 NUMBER OF TRIALS TO LEARNING 4CMS	COLUMNS 3-4 NUMBER OF TRIALS TO LEARNING 9CMS	COLUMNS 5-6 NUMBER OF TRIALS TO LEARNING 13CMS	COLUMNS 7-8 NUMBER OF TRIALS 5 MIN RETENTION 4CMS	COLUMNS 9-10 NUMBER OF TRIALS 5 MIN RETENTION 9CMS	COLUMNS 11-12 NUMBER OF TRIALS 5 MIN RETENTION 13CMS	COLUMNS 13-14 NUMBER OF TRIALS 24 HOUR RETENTION 4CMS	COLUMNS 15-16 NUMBER OF TRIALS 24 HOUR RETENTION 9CMS	COLUMNS 17-18 NUMBER OF TRIALS 24 HOUR RETENTION 13CMS	COLUMNS 69-70 DATA DECK NUMBER	COLUMNS 72-73 SUBJECT NUMBER	COLUMNS 75-80 SEX
160716050510572023											09 02	MALE
160716010102190726											09 03	MALE
160716130008020302											09 04	MALE
160716340311160104											09 05	MALE
160716210720160904											09 06	MALE
160716220510110709											09 07	MALE
160716092120120403											09 08	MALE
290818050103050607											09 09	MALE
030909010819100701											09 10	MALE
311009100206131506											09 11	MALE
041113030902070911											09 12	MALE
210128060119040111											09 13	MALE
050410050101081218											09 14	MALE
240730090601080916											09 15	MALE
131006021804321008											09 02	FEMALE
131006572016120614											09 03	FEMALE
131006050202150805											09 04	FEMALE
131006070901050401											09 05	FEMALE
131006050105101602											09 06	FEMALE
130912160805080603											09 07	FEMALE
110804041005091811											09 08	FEMALE
211111100405170601											09 09	FEMALE
120604050609030204											09 10	FEMALE
292003030102110810											09 11	FEMALE
110406020701011109											09 12	FEMALE
102410090720031705											09 13	FEMALE
051004051601100509											09 14	FEMALE
090406010410010304											09 15	FEMALE

MEAN ABSOLUTE ERROR OF ANGLES IN DEGREES OF MOTOR SHADOWING IN CUED RETRIEVAL
FOR LENGTHS 9CMS, 13CMS, 9 & 13CMS AND 4, 9 & 13CMS

FORMAT (4FS,2)
COLUMNS 1-5 LENGTH 9CMS
COLUMNS 6-10 LENGTH 13CMS
COLUMNS 11-15 LENGTHS 9 & 13CMS
COLUMNS 16-20 LENGTHS 4, 9 & 13CMS
COLUMNS 69-70 DATA DECK NUMBER
COLUMNS 72-73 SUBJECT NUMBER
COLUMNS 75-80 SEX

02350050000233301867	10	01	MALE
08050022000590006225	10	02	MALE
01867073330810004000	10	03	MALE
01500025500220004600	10	04	MALE
04000052000740007400	10	05	MALE
03000005000540009333	10	06	MALE
05200010000825006533	10	07	MALE
01350065000745001600	10	08	MALE
05200070000900009750	10	09	MALE
05200040000733308500	10	10	MALE
04600054000900007000	10	11	MALE
02700025500163301800	10	12	MALE
03100030500203307050	10	13	MALE
00000015000550000667	10	14	MALE
00000037000375002867	10	15	MALE
06833013000420004000	10	01	FEMALE
03800031000290002325	10	02	FEMALE
05200070000850004775	10	03	FEMALE
05200040000733301067	10	04	FEMALE
05200000000516704967	10	05	FEMALE
06150051000520003667	10	06	FEMALE
07150041000630004000	10	07	FEMALE
10300037000500001850	10	08	FEMALE
08100018500390001650	10	09	FEMALE
08100044000220006300	10	10	FEMALE
00200000000470009333	10	11	FEMALE
00500055000176701675	10	12	FEMALE
08100094500463304433	10	13	FEMALE
06350064000143305725	10	14	FEMALE
031000600000283301425	10	15	FEMALE

MEAN ABSOLUTE ERROR OF LENGTHS IN CENTIMETERS OF MOTOR SHADOWING IN CUED
RETRIEVAL FOR LENGTHS 9CMS, 13CMS, 9 & 13CMS AND 4, 9 & 13CMS

FORMAT (AF5.3)

COLUMNS 1-5 LENGTH 9CMS

COLUMNS 6-10 LENGTH 13CMS

COLUMNS 11-15 LENGTHS 9 & 13CMS

COLUMNS 16-20 LENGTHS 4, 9 & 13CMS

COLUMNS 69-70 DATA DECK NUMBER

COLUMNS 72-73 SUBJECT NUMBER

COLUMNS 75-80 SEX

02617016530205004290
04423061000631703935
02348080300356706750
00940052600453006858
06550062401193008280
01340032600461508208
05010065700321006625
02495117180305004973
08595081650544508375
C3975025260968406833
C564404410877903235
02676045740220601772
01248045220314505359
07050081610501906230
10860017060346002701
C5550034400063007900
04945043000323505915
07470089201686308015
05325067300974004080
04605063900697510160
02233041530268804168
04010040070613107225
03276070470184802776
08708009220165902550
04C35037080364000978
01430111481424505375
05982036350530200636
05789069741008402712
04317080850481908500
01040081110246401032

14 01 MALE
14 02 MALE
14 03 MALE
14 04 MALE
14 05 MALE
14 06 MALE
14 07 MALE
14 08 MALE
14 09 MALE
14 10 MALE
14 11 MALE
14 12 MALE
14 13 MALE
14 14 MALE
14 15 MALE
14 01 FEMALE
14 02 FEMALE
14 03 FEMALE
14 04 FEMALE
14 05 FEMALE
14 06 FEMALE
14 07 FEMALE
14 08 FEMALE
14 09 FEMALE
14 10 FEMALE
14 11 FEMALE
14 12 FEMALE
14 13 FEMALE
14 14 FEMALE
14 15 FEMALE

MEAN ABSOLUTE ERROR OF ANGLES IN DEGREES OF MOTOR SHADOWING IN NON-CUED
RETRIEVAL FOR LENGTHS 9CMS. 13CMS. 9 & 13CMS AND 4. 9 & 13CMS

FORMAT (AF5.2)

COLUMNS 1-5 LENGTH 9CMS
COLUMNS 6-10 LENGTH 13CMS
COLUMNS 11-15 LENGTHS 9 & 13CMS
COLUMNS 16-20 LENGTHS 4. 9 & 13CMS
COLUMNS 69-70 DATA DECK NUMBER
COLUMNS 72-73 SUBJECT NUMBER
COLUMNS 75-80 SEX

03400056000933304267	12	01	MALE
03900015000933307850	12	02	MALE
08100085000315006100	12	03	MALE
04925092670506704150	12	04	MALE
09750078000850005600	12	05	MALE
09000078000933307700	12	06	MALE
02500062000800005550	12	07	MALE
05400128000520009333	12	08	MALE
07075092000366704200	12	09	MALE
04450081000933302233	12	10	MALE
09000052000605006200	12	11	MALE
05867025000370002275	12	12	MALE
03350068500555004000	12	13	MALE
00800052000295005750	12	14	MALE
04800079000143302500	12	15	MALE
07500090000400006500	12	01	FEMALE
00900083500437503675	12	02	FEMALE
05900088001000004000	12	03	FEMALE
02800052000700008350	12	04	FEMALE
09000065000933304600	12	05	FEMALE
03800090000296704267	12	06	FEMALE
01933073330280004100	12	07	FEMALE
04350074500933304650	12	08	FEMALE
08500015000205003175	12	09	FEMALE
04500052000783303825	12	10	FEMALE
09000052001000007000	12	11	FEMALE
00100027000483303950	12	12	FEMALE
08500103500470006750	12	13	FEMALE
02150026500315000433	12	14	FEMALE
029000084000680004525	12	15	FEMALE

MEAN ABSOLUTE ERROR OF LENGTHS IN CENTIMETERS OF MOTOR SHADOWING IN NON-CUED
RETRIEVAL FOR LENGTHS 9CMS, 13CMS, 9 & 13CMS AND 4, 9 & 13CMS

FORMAT (4F5.3)
COLUMNS 1-5 LENGTH 9CMS
COLUMNS 6-10 LENGTH 13CMS
COLUMNS 11-15 LENGTHS 9 & 13CMS
COLUMNS 16-20 LENGTHS 4, 9 & 13CMS
COLUMNS 69-70 DATA DECK NUMBER
COLUMNS 72-73 SUBJECT NUMBER
COLUMNS 75-80 SEX

05720054580900705742	16 01	MALE
1163805857070306380	16 02	MALE
04053040570723302540	16 03	MALE
10638045620573203392	16 04	MALE
06010077780292005920	16 05	MALE
C9928102100327507763	16 06	MALE
C3240049650256004953	16 07	MALE
05580052830211507358	16 08	MALE
04966082660430804603	16 09	MALE
06203037710664804332	16 10	MALE
04680097210786602676	16 11	MALE
02668040770277304750	16 12	MALE
02856033090609108103	16 13	MALE
06049044920636409918	16 14	MALE
06490048970784505113	16 15	MALE
C1705027900198506450	16 01	FEMALE
07508002600585705842	16 02	FEMALE
10800082830786509970	16 03	FEMALE
06977043350306009700	16 04	FEMALE
08172052400834504145	16 05	FEMALE
02899035350529304992	16 06	FEMALE
04204025290530304048	16 07	FEMALE
12689076531113810466	16 08	FEMALE
02706077630171109967	16 09	FEMALE
01049032310907103388	16 10	FEMALE
06833050000711009967	16 11	FEMALE
04772021750194804041	16 12	FEMALE
01930023250252100678	16 13	FEMALE
08654025170631510352	16 14	FEMALE
03970012140134203261	16 15	FEMALE

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